

**FORTRAN IV COMPUTER PROGRAM FOR THE EVALUATION  
 OF NATURAL FREQUENCIES AND UNSTABLE  
 VALUES OF THE THRUST FREQUENCY FOR A  
 CIRCULAR CYLINDRICAL SHELL  
 SUBJECTED TO A GIMBALED PERIODICALLY VARYING END THRUST**

Research & Analysis Section Tech. Memo. #100

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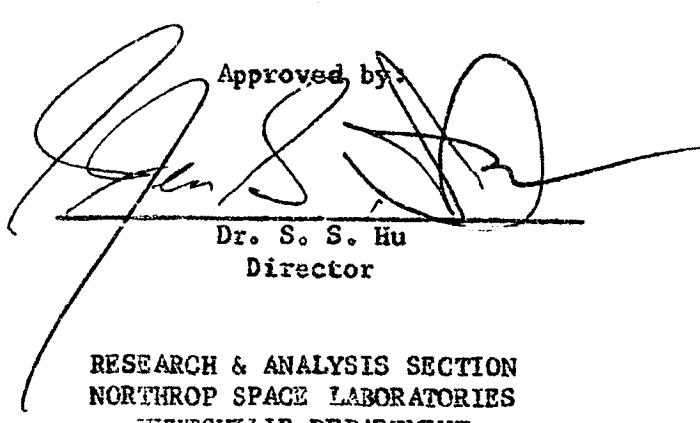
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## 1.0 INTRODUCTION

This report presents a FORTRAN IV Computer Program that operationally is compatible with the FORTRAN processors of the IBM 7094 and the UNIVAC 1107 digital computers. Additional details regarding the individual processors, actual machine compilation and object program execution, and so forth, are available in separate programming and operations reference manuals.

Specifically, this report presents a FORTRAN IV Computer Program that evaluates the natural frequencies of a thin cylindrical shell with simply-supported edge conditions [Eq. (47)] (all equation numbers in square brackets in this report are those appearing in ref. (1)) and then evaluates unstable values of the thrust frequency for given [Eq. (56)] initial conditions.

The Section 2.0 STABILITY CONSIDERATIONS-is presented in this report to facilitate the reader's understanding of the equations that are solved by the computer program (main program and subroutines) which is discussed at some length in the Section 3.0-FORTRAN IV COMPUTER PROGRAM. The reader may refer to APPENDIX A. - GENERAL INFORMATION ON THE SOLUTION OF THE STABILITY EQUATIONS - for mathematical details on the method of iteration used in the FORTRAN IV Computer Program.

## 2.0 STABILITY CONSIDERATIONS

### 2.1 Development of Equations

Since this report is to be regarded as a companion report to the report, "Response of A Circular Cylindrical Shell to a Gimbaled Periodically Varying End Thrust", Technical Memo. #38, Research and Analysis Section, Northrop Space Laboratories, Huntsville, Alabama, November 20, 1964, all equations presented in this report will have the numbers of those same equations in Tech. Memo. #38, shown in square brackets.

As presented in Tech. Memo. #38, the Matheau equation is

$$\frac{d^2 a}{dt_1^2} + (a - 2q \cos 2t_1)a = 0 \quad (1), \quad [16]$$

where

$$a = \frac{8\pi RL T_K}{I\Omega^2}, \quad q = \frac{\pi a}{2} \quad (2), \quad [15]$$

with ranges

$$0 < a < 1, \quad 0 < q \leq 0.05 \quad (3), \quad [17]$$

Without detailed derivation (see p. 40 of ref. 2) it is shown that the

$$\sin^2 \frac{R\pi}{2} = \Delta(0) \sin^2 \frac{\pi a^{\frac{1}{2}}}{2} \quad (4), \quad [21]$$

where for small values of  $q$

$$\Delta(0) = 1 + \frac{\pi q^2}{4a^{\frac{1}{2}}(1-a)} \cot \frac{\pi a^{\frac{1}{2}}}{2} \quad (5), \quad [22]$$

which, after substituting  $q = \gamma a/2$  and simplifying becomes

$$\Delta(0) = 1 + \frac{\frac{3}{2} \gamma^2}{16(1-a)} \cot \frac{\frac{\pi a}{2}}{2} \quad (6) \text{ [not listed]}$$

The expression for  $\beta$  is written

$$\beta = \frac{2}{\pi} \left[ \sin^{-1} \left\{ [\Delta(0)]^{\frac{1}{2}} \sin \frac{\frac{\pi a}{2}}{2} \right\} \right] \quad (7) \text{ [not listed]}$$

which shows that  $\beta$  is a function of  $a$  by virtue of equation (6) and equation (2) in this report. The transcendental stability equations will now be presented.

## 2.2 Presentation of Stability Equations

### 2.2.1 Subroutine UNST1 solves Equation [82]

$$\overbrace{[(m-2)^2 + \epsilon_m^{\beta}] \frac{\Omega}{a}}^{(1)} = \omega_{0k}$$

where

$$\epsilon_m = \begin{cases} -\frac{1}{2} & \text{if } m=1 \\ \frac{1}{2} & \text{if } m=2 \\ \frac{1}{2} & \text{if } m=3 \end{cases} \quad \begin{matrix} k = 1, 2, \dots N \\ m = 1, 2, 3 \end{matrix}$$

<u>m</u>	<u>(1)</u>	<u>k</u>	<u><math>\omega_{0k}</math></u>
1	$1 - \frac{a}{2}$	1	$\omega_{01}$
2	$\frac{a}{2}$	2	$\omega_{02}$
3	$1 + \frac{a}{2}$	3	$\omega_{03}$
	"	"	"
	"	"	"
	"	"	"
N			$\omega_{0N}$

2.2.2 Subroutine UNST2 solves Equation [83]

$$\frac{\Omega}{\omega} = \frac{\omega^i}{\omega_{j0}}$$

where

$$i = 1, 2$$

$$j = 1, 2, \dots, M$$

<u>1</u>	1	<u><math>\omega_{j0}^1</math></u>
1	1	$\omega_{10}^1$
2	1	$\omega_{10}^2$
1	2	$\omega_{20}^1$
2	2	$\omega_{20}^2$
1	3	$\omega_{30}^1$
2	3	$\omega_{30}^2$
.	.	.
.	.	.
.	.	.
.	.	.
1	M	<u><math>\omega_{M0}^1</math></u>
2	M	$\omega_{M0}^2$

2.2.3 Subroutine UNST3 solves Equation [84]

$$\textcircled{2} \quad \overline{\left| (m-2)^2 + (n-2)^2 + (\epsilon_m - \epsilon_n)\beta \right|} \frac{\Omega}{\omega} = \omega_{j0}^i$$

where

$$i = 1, 2$$

$$j = 1, 2, \dots, M$$

$$m = 1, 2, 3$$

$$n = 1, 2, 3 \quad \text{---}$$

$$\epsilon_m = \begin{cases} -\frac{1}{2} & \text{if } m=1 \\ \frac{1}{2} & \text{if } m=2 \\ \frac{1}{2} & \text{if } m=3 \end{cases}$$

$$\epsilon_n = \begin{cases} -\frac{1}{2} & \text{if } n=1 \\ \frac{1}{2} & \text{if } n=2 \\ \frac{1}{2} & \text{if } n=3 \end{cases}$$

<u>i</u>	<u>j</u>	<u><math>\omega_{j0}^i</math></u>	<u>n</u>	<u>m</u>	<u>(2)</u>
1	1	$\omega_{10}^1$	1	1	not admissible
2	1	$\omega_{10}^2$	2	1	$-1 + \beta$
1	2	$\omega_{20}^1$	3	1	$\beta$
2	2	$\omega_{20}^2$	1	2	$1 - \beta$
1	3	$\omega_{30}^1$	2	2	not admissible
2	3	$\omega_{30}^2$	3	2	1
.	.	.	1	3	$-\beta$
.	.	.	2	3	$-1$
.	.	.	3	3	not admissible
.	.	.			
1	M	$\omega_{M0}^1$			
2	M	$\omega_{M0}^2$			

#### 2.2.4 Subroutine UNST4 solves Equation [85]

$$\underbrace{(\textcircled{3})}_{\left| (\text{m}-2)^2 + (\text{n}-2)^2 + (\epsilon_{\text{m}} + \epsilon_{\text{n}}) \beta \right| \frac{\Omega}{\omega} = \omega_{j0}^i}$$

where

$$i = 1, 2$$

$$j = 1, 2, \dots M$$

$$m = 1, 2, 3$$

$$n = 1, 2, 3$$

$$\epsilon_m = \begin{cases} -\frac{1}{2} & \text{if } m=1 \\ \frac{1}{2} & \text{if } m=2 \\ \frac{1}{2} & \text{if } m=3 \end{cases}$$

$$\epsilon_n = \begin{cases} -\frac{1}{2} & \text{if } n=1 \\ \frac{1}{2} & \text{if } n=2 \\ \frac{1}{2} & \text{if } n=3 \end{cases}$$

<u>i</u>	<u>j</u>	<u><math>\omega_{j0}^i</math></u>	<u>m</u>	<u>n</u>	<u>(3)</u>
1	1	$\omega_{10}^1$	1	1	not admissible
2	1	$\omega_{10}^2$	2	1	1
1	2	$\omega_{20}^1$	3	1	2
2	2	$\omega_{20}^2$	1	2	1
1	3	$\omega_{30}^1$	2	2	not admissible
2	3	$\omega_{30}^2$	3	2	$1 + \beta$
.	.	.	1	3	2
.	.	.	2	3	$1 + \beta$
1	M	$\omega_{M0}^1$	3	3	not admissible
2	M	$\omega_{M0}^2$			

2.2.5 Subroutine UNST5 solves Equation [86]

(4)

$$2[(m-2)^2 + \epsilon_m \beta] \frac{\Omega}{\omega} = \omega_{j0}^i$$

where

$$i = 1, 2$$

$$j = 1, 2, \dots M$$

$$m = 1, 2, 3$$

$$\epsilon_m = \begin{cases} -\frac{1}{2} & \text{if } m=1 \\ \frac{1}{2} & \text{if } m=2 \\ \frac{1}{2} & \text{if } m=3 \end{cases}$$

<u>i</u>	<u>j</u>	<u><math>\omega_{j0}^i</math></u>	<u>m</u>	<u>(4)</u>
1	1	$\omega_{10}^1$	1	$2 - \beta$
2	1	$\omega_{10}^2$	2	$\beta$
1	2	$\omega_{20}^1$	3	$2 + \beta$
2	2	$\omega_{20}^2$		
1	3	$\omega_{30}^1$		
2	3	$\omega_{30}^2$		
.	.	.		
.	.	.		
.	.	.		
.	.	.		
1	M	$\omega_{M0}^1$		
2	M	$\omega_{M0}^2$		

### 2.2.6 Subroutine UNST6 solves Equation [87]

$$\underbrace{[(m-2)^2 + \epsilon_m \beta] \frac{\Omega}{\omega}}_{(5)} = \omega_{jk}^i$$

where

$$i = 1, 2, 3$$

$$j = 1, 2, \dots M$$

$$k = 1, 2, \dots N$$

$$m = 1, 2, 3$$

$$\epsilon_m = \begin{cases} -\frac{1}{2} & \text{if } m=1 \\ \frac{1}{2} & \text{if } m=2 \\ \frac{1}{2} & \text{if } m=3 \end{cases}$$

<u>i</u>	<u>j</u>	<u><math>\omega_{jk}^i</math></u>	<u>k</u>	<u>m</u>	<u>(5)</u>
1	1	$\omega_{1k}^1$	$k = 1, 2, \dots N$	1	$1 - \frac{1}{2}\beta$
2	1	$\omega_{1k}^2$	.	2	$\frac{1}{2}\beta$
3	1	$\omega_{1k}^3$	.	3	$1 + \frac{1}{2}\beta$
1	2	$\omega_{2k}^1$	.		
2	2	$\omega_{2k}^2$	.		
3	2	$\omega_{2k}^3$	.		
1	3	$\omega_{3k}^1$	.		
2	3	$\omega_{3k}^2$	.		
3	3	$\omega_{3k}^3$	.		
.	.	.	.		
.	.	.	.		
.	.	.	.		
1	M	$\omega_{Mk}^1$	.		
2	M	$\omega_{Mk}^2$	.		
3	M	$\omega_{Mk}^3$	$k = 1, 2, \dots N$		

2.2.7 Subroutine UNST7 solves Equation [88]

$$\underbrace{|(m-2)^2 - 1 + \epsilon_m \beta|}_{(6)}^{\Omega} = \omega_{jk}^i$$

where

$$i = 1, 2, 3$$

$$j = 1, 2, \dots M$$

$$k = 1, 2, \dots N$$

$$m = 1, 2, 3$$

$$\epsilon_m = \begin{cases} -\frac{1}{2} & \text{if } m=1 \\ \frac{1}{2} & \text{if } m=2 \\ \frac{1}{2} & \text{if } m=3 \end{cases}$$

<u>i</u>	<u>j</u>	<u><math>\omega_{jk}^i</math></u>	<u>k</u>	<u>m</u>	<u>(6)</u>
1	1	$\omega_{1k}^1$	$k = 1, 2, \dots N$	1	$-\frac{1}{2}\beta$
2	1	$\omega_{1k}^2$	.	2	$-1 + \frac{1}{2}\beta$
3	1	$\omega_{1k}^3$	.	3	$\frac{1}{2}\beta$
1	2	$\omega_{2k}^1$	.		
2	2	$\omega_{2k}^2$	.		
3	2	$\omega_{2k}^3$	.		
1	3	$\omega_{3k}^1$	.		
2	3	$\omega_{3k}^2$	.		
3	3	$\omega_{3k}^3$	.		
.	.	.	.		
.	.	.	.		
.	.	.	.		
1	M	$\omega_{Mk}^1$	.		
2	M	$\omega_{Mk}^2$	.		
3	M	$\omega_{Mk}^3$	$k = 1, 2, \dots N$		

### 2.2.8 Subroutine UNST8 solves Equation [89]

$$\overbrace{ |(m-2)^2 + 1 + \epsilon_m \beta | \frac{\Omega}{\omega} }^{(7)} = \omega_{jk}^i$$

where

$$i = 1, 2, 3$$

$$j = 1, 2, \dots, M$$

$$k = 1, 2, \dots, N$$

$$m = 1, 2, 3$$

$$\epsilon_m = \begin{cases} -\frac{1}{2} & \text{if } m=1 \\ \frac{1}{2} & \text{if } m=2 \\ \frac{1}{2} & \text{if } m=3 \end{cases}$$

i	j	$\omega_{jk}^i$	k	m	(7)
1	1	$\omega_{1k}^1$	$k = 1, 2, \dots, N$	1	$2 - \frac{1}{2}\beta$
2	1	$\omega_{1k}^2$	.	2	$1 + \frac{1}{2}\beta$
3	1	$\omega_{1k}^3$	.	3	$2 + \frac{1}{2}\beta$
1	2	$\omega_{2k}^1$	.		
2	2	$\omega_{2k}^2$	.		
3	2	$\omega_{2k}^3$	.		
1	3	$\omega_{3k}^1$	.		
2	3	$\omega_{3k}^2$	.		
3	3	$\omega_{3k}^3$	.		
.	.	.	.		
.	.	.	.		
.	.	.	.		
1	M	$\omega_{Mk}^1$	.		
2	M	$\omega_{Mk}^2$	.		
3	M	$\omega_{Mk}^3$	$k = 1, 2, \dots, N$		

2.2.9 Subroutine UNST9 solves Equation [90]

(8)

$$\overbrace{[(m-2)^2 + (n-2)^2 + (\epsilon_m - \epsilon_n)\beta]}^8 | \frac{\Omega}{\omega} = w_{jk}^i$$

where

$$\begin{aligned} i &= 1, 2, 3 \\ j &= 1, 2, \dots, M \\ k &= 1, 2, \dots, N \\ m &= 1, 2, 3 \\ n &= 1, 2, 3 \quad m \neq n \end{aligned}$$

$$\epsilon_m = \begin{cases} -\frac{1}{2} & \text{if } m=1 \\ \frac{1}{2} & \text{if } m=2 \\ \frac{1}{2} & \text{if } m=3 \end{cases}$$

$$\epsilon_n = \begin{cases} -\frac{1}{2} & \text{if } n=1 \\ \frac{1}{2} & \text{if } n=2 \\ \frac{1}{2} & \text{if } n=3 \end{cases}$$

<u>i</u>	<u>j</u>	<u>w<sub>jk</sub><sup>i</sup></u>	<u>k</u>	<u>m</u>	<u>n</u>	<u>(8)</u>
1	1	$w_{1k}^1$	$k = 1, 2, \dots, N$	1	1	not admissible
2	1	$w_{1k}^2$	.	2	1	$-1 + \beta$
3	1	$w_{1k}^3$	.	3	1	$\beta$
1	2	$w_{2k}^1$	.	1	2	$1 - \beta$
2	2	$w_{2k}^2$	.	2	2	net admissible
3	2	$w_{2k}^3$	.	3	2	1
1	3	$w_{3k}^1$	.	1	3	$-\beta$
2	3	$w_{3k}^2$	.	2	3	$-\beta$
3	3	$w_{3k}^3$	.	3	3	net admissible
.	.	.	.			
.	.	.	.			
.	.	.	.			
1	M	$w_{Mk}^1$	.			
2	M	$w_{Mk}^2$	.			
3	M	$w_{Mk}^3$	$k = 1, 2, \dots, N$			

2.2.10 Subroutine UNST10 solves Equation [91]

(9)

$$|(\omega_m - 2)^2 + (\omega_n - 2)^2 + (\epsilon_m + \epsilon_n) \beta | \frac{\Omega}{\omega} = \omega_{jk}^i$$

where

$$\begin{aligned} i &= 1, 2, 3 \\ j &= 1, 2, \dots, M \\ k &= 1, 2, \dots, N \\ m &= 1, 2, 3 \quad m \neq n \\ n &= 1, 2, 3 \end{aligned}$$

$$\epsilon_m = \begin{cases} -\frac{1}{2} & \text{if } m=1 \\ \frac{1}{2} & \text{if } m=2 \\ \frac{1}{2} & \text{if } m=3 \end{cases}$$

$$\epsilon_n = \begin{cases} -\frac{1}{2} & \text{if } n=1 \\ \frac{1}{2} & \text{if } n=2 \\ \frac{1}{2} & \text{if } n=3 \end{cases}$$

<u>i</u>	<u>j</u>	<u><math>\omega_{jk}^i</math></u>	<u>k</u>	<u>m</u>	<u>n</u>	(9)
1	1	$\omega_{1k}^1$	$k = 1, 2, \dots, N$	1	1	not admissible
2	1	$\omega_{1k}^2$	.	2	12	1
3	1	$\omega_{1k}^3$	.	3	1	2
1	2	$\omega_{2k}^1$	.	1	2	1
2	2	$\omega_{2k}^2$	.	2	2	not admissible
3	2	$\omega_{2k}^3$	.	3	2	$1 + \beta$
1	3	$\omega_{3k}^1$	.	1	3	2
2	3	$\omega_{3k}^2$	.	2	3	$1 + \beta$
3	3	$\omega_{3k}^3$	.	3	3	not admissible
.	.	.	.	.	.	
.	.	.	.	.	.	
.	.	.	.	.	.	
1	M	$\omega_{Mk}^1$	.			
2	M	$\omega_{Mk}^2$	.			
3	M	$\omega_{Mk}^3$	$k = 1, 2, \dots, N$			

2.2.11 Subroutine UNST11 solves Equation [92]

$$\underbrace{2[(m-2)^2 + \epsilon_m s] \frac{\Omega}{\omega}}_{(10)} = \omega_{jk}^i$$

where

$$i = 1, 2, 3$$

$$j = 1, 2, \dots, M$$

$$k = 1, 2, \dots, N$$

$$m = 1, 2, 3$$

and

$$\epsilon_m = \begin{cases} -\frac{1}{2} & \text{if } m=1 \\ \frac{1}{2} & \text{if } m=2 \\ \frac{1}{2} & \text{if } m=3 \end{cases}$$

i	j	$\omega_{jk}^i$	k	m	(10)
1	1	$\omega_{1k}^1$	$k = 1, 2, \dots, N$	1	$2 - 8$
2	1	$\omega_{1k}^2$	*	2	8
3	1	$\omega_{1k}^3$	*	3	$2 + 8$
1	2	$\omega_{2k}^1$	*		
2	2	$\omega_{2k}^2$	*		
3	2	$\omega_{2k}^3$	*		
1	3	$\omega_{3k}^1$	*		
2	3	$\omega_{3k}^2$	*		
3	3	$\omega_{3k}^3$	*		
*	*	*	*		
*	*	*	*		
*	*	*	*		
1	M	$\omega_{Mk}^1$	*		
2	M	$\omega_{Mk}^2$	*		
3	M	$\omega_{Mk}^3$	$k = 1, 2, \dots, N$		

### 2.3 Limiting Cases

#### 2.3.1 Limiting case of $\beta$ for $\Delta(0) = 1$ .

Referring to equation (7) in this report, the expression for  $\beta$  is presented again

$$\beta = \frac{2}{\pi} \left\{ \sin^{-1} \left[ [\Delta(0)]^{\frac{1}{2}} \sin \frac{\pi a^{\frac{1}{2}}}{2} \right] \right\} \quad (7)$$

For the limiting case of  $\Delta(0) = 1$ , the equation becomes

$$\beta = a^{\frac{1}{2}} = \frac{2}{\pi} \left( \frac{2\pi rHT_K}{I} \right)^{\frac{1}{2}} \quad (8)$$

#### 2.3.2 Limiting Cases of the Parameter $a$

Referring to equation (6) in this report, the expression for  $\Delta(0)$  is presented again

$$\Delta(0) = 1 + \frac{\pi a^{3/2} I^2}{16(1-a)} \cot \frac{\pi a^{\frac{1}{2}}}{2} \quad (6)$$

It can be shown, by the application of L'Hospital's rule on limits, that the following limits exist

$$\lim_{a \rightarrow 0} \left( \frac{\pi a^{3/2} I^2}{16(1-a)} \cot \frac{\pi a^{\frac{1}{2}}}{2} \right) = 0 \quad (9)$$

$$\lim_{a \rightarrow 1} \left( \frac{\pi a^{5/2} I^2}{16(1-a)} \cot \frac{\pi a^{\frac{1}{2}}}{2} \right) = \frac{\pi^2 I^2}{64} \quad (10)$$

As shown by the results of equations (9) and (10) the following value and/or expression for  $\Delta(0)$  exists

$$\Delta(0) \rightarrow 1 \text{ as } a \rightarrow 0$$

$$\Delta(0) \rightarrow 1 + \frac{\pi^2 Y}{16} \text{ as } a \rightarrow 1$$

A small table of values of  $\Delta(0)$  for selected values of  $\gamma$  is presented below

<u><math>\Delta(0)</math></u> as $a \rightarrow 0$	<u><math>\Delta(0)</math></u> as $a \rightarrow 1$	<u><math>\gamma</math></u>	<u><math>\gamma^2</math></u>
1	1.0000154	0.01	$1.00 \times 10^{-4}$
1	1.0003850	0.05	$2.50 \times 10^{-3}$
1	1.0015400	0.10	$1.00 \times 10^{-2}$
1	1.0096300	0.25	$6.25 \times 10^{-2}$
1	1.0385000	0.50	$25.0 \times 10^{-2}$

### 3.0 FORTRAN IV COMPUTER PROGRAM

#### 3.1 General

The following FORTRAN IV Computer Program has been developed to calculate the natural frequencies and the unstable values of thrust frequency from data consisting of the parameters,  $H$ ,  $r$ ,  $t$ ,  $\rho$ ,  $E$ ,  $v$ ,  $\omega$ ,  $m$ ,  $n$ ,  $T_0$ ,  $\gamma$ ,  $\Omega$ ,  $\Delta\Omega$  and  $K$ . The manner in which these data words are read into the computer is presented under FORTRAN IV COMPUTER PROGRAM INPUT AND OUTPUT INFORMATION of this report.

The computer program consists of the following parts:

- 3.1.1 Main Program - FORTRAN IV Computer Program for the Evaluation of Natural Frequencies (OMG) and Unstable Values of the Thrust Frequency (COMG) for a Simply-Supported, Circular Cylindrical Shell.
- 3.1.2 Subroutine NAFREQ - Subroutine for the Evaluation of Natural Frequencies (OMG). Subroutine calculates 10-values of  $OMG(O, K, I)$ , 20-values of  $OMG(J, O, I)$  and 300-values of  $OMG(J, K, I)$ .
- 3.1.3 Subroutine UNST1 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [82]. Consideration of three (3) cases, involving 30 values.
- 3.1.4 Subroutine UNST2 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [83]. Consideration of one (1) case, involving 20 values.

- 3.1.5 Subroutine UNST3 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [84]. Consideration of nine (9) cases (3-inadmissible), involving 120 values.
- 3.1.6 Subroutine UNST4 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [85]. Consideration of nine (9) cases (3 inadmissible), involving 120 values.
- 3.1.7 Subroutine UNST5 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [86]. Consideration of three (3) cases, involving 60 values.
- 3.1.8 Subroutine UNST6 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [87]. Consideration of three (3) cases, involving 900 values.
- 3.1.9 Subroutine UNST7 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [88]. Consideration of three (3) cases, involving 900 values.
- 3.1.10 Subroutine UNST8 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [89]. Consideration of three (3) cases, involving 900 values.
- 3.1.11 Subroutine UNST9 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [90]. Consideration of nine (9) cases (3 inadmissible), involving 1800 values.
- 3.1.12 Subroutine UNST10 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [91]. Consideration of nine (9) cases (3 inadmissible), involving 1800 values.

**3.1.13 Subroutine UNST11 - Subroutine for Unstable Values of Thrust Frequency, COMG, Equation [92]. Consideration of three (3) cases, involving 900 values.**

**3.2 FORTRAN IV Legend for Input Data**

The FORTRAN IV designation for input data is as follows:

<u>Input Parameter</u>	<u>FORTRAN IV Name</u>
H, half length	H
r, radius	R
t, thickness	T
$\rho$ , mass density	RHO
E, modulus	E
v, Poisson's ratio	V
w, test frequency	W
m, axial variation term	M
n, radial variation term	N
$T_0$ , constant thrust	TO
$\gamma$ , ratio, variable to constant thrust	GAM
$\Omega$ , thrust frequency	COMG
K, control constant	CK

Full details on the manner in which these data are read into the computer is presented under FORTRAN IV Computer Program Input and Output Information.

### 3.3 FORTRAN IV Legend for Computed Variables

Due to the restrictions on variable names in the FORTRAN IV language, many of the computed variables were reassigned. The following table gives a complete list of computed variables and their corresponding FORTRAN IV designation.

$\omega_{jk}^i$ , natural frequency	OMG(J,K,I)
$\Omega_{jk}^i$ , thrust frequency	COMG(J,K,I)
$a_{jk}^i$	A(J,K,I)
$b_{jk}^i$	B(J,K,I)
$[\Delta(0)]_{jk}^i$	DELO(J,K,I)
$c_{jk}^i$	C(J,K,I)
$d_{jk}^i$	D(J,K,I)
$f_{jk}^i$	F(J,K,I)
$\beta_{jk}^i$	BETA(J,K,I)
$(\beta/2)_{jk}^i$	BETA12(J,K,I)
$\epsilon_1^{(1)}, \epsilon_1^{(2)}$	F1(L)
$x_1, x_2$	X(L)
$d_1$	D1
$t_1$	C1
$\bar{z}_2$	C2

Range on subscripts:  $j = 0, 1, \dots, M$   
 $k = 0, 1, \dots, N$   
 $i = 1, 2, 3$

### 3.4 FORTRAN IV Computer Program Input and Output Information

#### 3.4.1 Input

The input data which must be punched on cards are the terms H, R, T, RHO, E, V, W, M, N, TO, GAM, COMG, CK. These data are punched on two cards.

The first data card will contain H in spaces 1 through 10, R in spaces 11 through 20, T in spaces 21 through 30, RHO in spaces 31 through 40, E in spaces 41 through 50, V in spaces 51 through 60, and W in spaces 61 through 70.

The second data card will contain M in spaces 1 through 5, N in spaces 6 through 10, TO in spaces 11 through 20, GAM in spaces 21 through 30, COMG in spaces 31 through 40, DCOMG in spaces 41 through 50 and CK in spaces 51 through 60.

The READ STATEMENTS for the first and second data card will be as follows:

```
2   READ(5,102) H, R, T, RHO, E, V, W  
102 FORMAT(7F10.5)  
  
3   READ(5, 103) M, N, TO, GAM, COMG, CK  
103 FORMAT (2I5, 4E10.5)
```

A definition of input data is given under FORTRAN IV Legend for Input Data.

### 3.4.2 Output

The values of natural frequencies  $\omega_{jk}^i$  [OMG(J,K,I)] are printed in floating point numbers except the values of J and K which are integer values.

The unstable values of the thrust frequency  $\Omega_{jk}^i$  [COMG(J,K,I)] are printed in floating point numbers except the values of J and K which are integer values. A descriptive title, properly identifying the equation number and the particular case, is printed before each section of the program printout.

## 3.5 FORTRAN IV Source Program

### 3.5.1 General Statement

The program which defines the operations which the computer is to do and which is written by the programmer in the FORTRAN IV language is called the FORTRAN IV Source Program. With this in mind, and with reference to the FORTRAN IV Legend for Computed Variables presented earlier in this report, the reader should have little difficulty in understanding the following Program Listing.

### 3.5.2 Program Listing

\*N. FOR IAFREQ  
 COMMON L,S,U,V,W,PI,M,N,OMG(20,20,3),R,H,TO,CK,RI,GAM  
 C NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)  
 C FORTRAN IV COMPUTER PROGRAM FOR THE EVALUATION OF NATURAL  
 C FREQUENCIES (OMG) AND UNSTABLE VALUES OF THE THRUST FREQUENCY  
 C (COMG) FOR A SIMPLY-SUPPORTED, CIRCULAR CYLINDRICAL SHELL.  
 REAL L  
 1 WRITE (6,100)  
 100 FORMAT(1H1,20X,31HLEGEND OF TERMS USED IN PROGRAM,/,5X,30HH ----  
 1HALF LENGTH OF CYLINDER,/,5X,25HR ---- RADIUS OF CYLINDER,/,5X,33H  
 2T THICKNESS OF CYLINDER WALL,/,5X,40HRHO -- MASS DENSITY OF C  
 3YLINDER MATERIAL,/,5X,38HE ---- YOUNGS MODULUS FOR THE MATERIAL,/,  
 45X,21HW ---- POISONS RATIO,/,5X,26HW ---- REFERENCE FREQUENCY,/,5  
 5X,38HN ---- NUMBER OF AXIAL VARIATION TERMS,/,5X,39HN ---- NUMBER  
 6OF RADIAL VARIATION TERMS,/,5X,30HJ,K -- SUBSCRIPTS OF THE APARRAY,/  
 7,5X,34HOMG(J,K,1) --- NATURAL FREQUENCY 1,/,5X,34HOMG(J,K,2) --- N  
 8ATURAL FREQUENCY 2,/,5X,34HOMG(J,K,3) --- NATURAL FREQUENCY 3,/,5X  
 9,28HTU --- CONSTANT THRUST FORCE,/,5X,38HGAM -- VARIABLE THRUST/CU  
 1INSTANT THRUST,/,5X,48HCOMG -- CAPITAL OMEGA, INSTABLE SEARCH FREQU  
 2ENCY,/,5X,39HDCOMG -- DELTA CAPITAL OMEGA, INCREMENT,/,5X,20HCK--C  
 3ONTROL CONSTANT)  
 2 READ (5,102) H,R,T,RHO,E,V,W  
 102 FORMAT (7F10.5)  
 3 READ (5,103) M,N,TO,GAM,COMG,DCOMG,CK  
 103 FORMAT (2I5,5E10.5)  
 4 WRITE (6,104) H,R,T,RHO,W,E,V,M,N,TO,GAM,COMG,DCOMG,CK  
 104 FORMAT(1H1,10X,62HUNSTABLE VALUES OF THE THRUST FREQUENCY(COMG) FU  
 1R THE CYLINDER,/,3X,14HHALF LENGTH = ,3PE15.5,10X,9HRADIUS = ,3PE  
 215.5,10X,12HTHICKNESS = ,1PE15.5,/,3X,15HMASS DENSITY = ,E15.8,9X  
 3,22HREFERENCE FREQUENCY = ,E15.5,/,3X,17HYOUNGS MODULUS = ,1PE15.  
 45,7X,17HPOISONS RATIO = ,E15.5,/,3X,34HNUMBER OF AXIAL VARIATION  
 5 TERMS = ,15,10X,35HNUMBER OF RADIAL VARIATION TERMS = ,15,/,3X,  
 62HCONSTANT THRUST, TO = ,1PE15.5,3X,6HGAM = ,E15.5,3X,21HCAPITAL O  
 7MEGA,COMG = ,E15.5,/,3X,28HDELTA CAPITAL OMEGA,DCOMG = ,E15.5,3X,  
 824HCONTROL CONSTANT K,CK = ,E15.5,/,)  
 P1=3.141592654  
 L=H/R  
 S=T/H  
 U=RHO\*H\*H\*W\*W/E  
 CALL IAFREQ (L,S,U,V,W,PI,M,N,OMG)  
 5 WRITE (6,105)  
 105 FORMAT (2UX,41HTABLE OF NATURAL FREQUENCIES, RAD PER SEC,/,4X,2HJU  
 1,0,4X,2HK,,8X,9HOME GA (1),11X,9HOME GA (2),10X,9HOME GA (3),//)  
 100 FORMAT (2I5,3L20.8//)  
 DO 6 J=1,M  
 DO 6 K=1,N  
 J1=J-1  
 K1=K-1  
 6 WRITE (6,106) J1,K1,(OMG(J,K,I),I=1,3)  
 RM=2.\*H\*2.\*P1\*R\*T\*RHO  
 RI=RM\*(.5\*R\*R+.333\*H\*H)\*386.  
 CALL UNST1 (P1,R,H,TO,CK,RI,GAM,OMG,M,N)  
 CALL UNST2 (P1,R,H,TO,CK,RI,GAM,OMG,M,N)  
 CALL UNST3 (P1,R,H,TO,CK,RI,GAM,OMG,M,N)  
 CALL UNST4 (P1,R,H,TO,CK,RI,GAM,OMG,M,N)  
 CALL UNST5 (P1,R,H,TO,CK,RI,GAM,OMG,M,N)  
 CALL UNST6 (P1,R,H,TO,CK,RI,GAM,OMG,M,N)  
 CALL UNST7 (P1,R,H,TO,CK,RI,GAM,OMG,M,N)  
 CALL UNST8 (P1,R,H,TO,CK,RI,GAM,OMG,M,N)  
 CALL UNST9 (P1,R,H,TO,CK,RI,GAM,OMG,M,N)

CALL UNST10(P1,R,H,T0,CK,RI,GAM,OMG,M,N)

CALL UNST11(P1,R,H,T0,CK,RI,GAM,OMG,M,N)

UC TU 2

END

```

FOR NAFREQ
NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)
SUBROUTINE FOR THE EVALUATION OF NATURAL FREQUENCIES(OMG).
SUBROUTINE CALCULATES 16 VALUES OF OMG(J,K,I), 20 VALUES OF
OMG(J,O,I), AND 300 VALUES OF OMG(J,K,I)
SUBROUTINE NAFREQ (L,S,U,V,W,PI,M,N,OMG)
DIMENSION A(3,3),ROOTR(3),ROUTI(3),OMG(20,20,3)
REAL L
U1=U*(1.-V*V)
DO 1 J=1,M
DO 1 K=1,N
DO 1 I=1,3
1 OMG(J,K,I)=U*U
DO 2 J=1,M
DO 2 K=1,N
JI=J-1
K1=K-1
FJ=FJ1
FK=K1
IF (J-1)3,3,4
3 IF (K-1)2,2,5
5 OMG(J,K,I)=L*FK*W/SQRT(2.*U*(1.+V))
GO TO 2
4 IF (K-1)6,6,7
6 A(1,1)=.25*(F1+FJ)**2/U1
A(1,2)=.5*V*L*FJ*PI/U1
A(2,1)=A(1,2)
A(2,2)=(L*L+S*S*(FJ*PI)**4/192.)/U1
CALL HESSEN(A,2)
CALL QREIG(A,2,ROOTR,ROUTI,0)
DO 8 I=1,2
IF (ROUTI(I))9,10,9
10 IF (ROOTR(I))9,11,11
9 WRITE (6,100)J,K,I,ROOTR(I),ROUTI(I)
100 FORMAT(23H0ROOT IS NOT ACCEPTABLE 3I5,2E15.8)
GO TO 8
11 OMG(J,K,I)=W*SQRT(ABS(ROOTR(1)))
12 CONTINUE
GO TO 2
7 A(1,1)=.25*((PI*FJ)**2+2.*((1.-V)*(L*FK)**2)/U1
A(1,2)=-.25*FJ*FK*PI*L*(1.+V)/U1
A(1,3)=.5*V*L*PI*FJ/U1
A(2,1)=A(1,2)
A(2,2)=.125*((1.-V)*(FJ*PI)**2+8.*((L*FK)**2)/U1
A(2,3)=-1.*L*L*FK/U1
A(3,1)=A(1,3)
A(3,2)=A(2,3)
A(3,3)=(12.*L*L+S*S*((.5*FJ*PI)**2+L*L*FK*FK)**2)/(12.*U1)
CALL HESSEN(A,3)
CALL QREIG(A,3,ROOTR,ROUTI,0)
DO 12 I=1,3
IF (ROUTI(I))13,14,13
14 IF (ROOTR(I))13,15,15
13 WRITE (6,101)J,K,I,ROOTR(I),ROUTI(I)
101 FORMAT(23H0ROOT IS NOT ACCEPTABLE,3I5,2E15.8)
GO TO 12
15 OMG(J,K,I)=W*SQRT(ABS(ROOTR(1)))
12 CONTINUE
2 CONTINUE
RETURN

```



```

      FOR HESSEN
      SUBROUTINE TO PUT MATRIX IN UPPER HESSENBERG FORM.
      SUBROUTINE HESSEN(A,M)
      DIMENSION A(3,3), B(2)
      DOUBLE PRECISION SUM
      IF (M = 2) 30,30,32
32 DO 40 LC = 3,M
      N = M - LC + 3
      N1 = N - 1
      N2 = N - 2
      NI = N1
      DIV = ABS(A(N,N-1))
      DO 2 J = 1,N2
      IF (ABS(A(N,J))= DIV) 2+2+1
1 NI = J
      DIV = ABS(A(N,J))
2 CONTINUE
      IF (DIV) 3,40,3
3 IF (NI = N1) 4, 7+4
4 DO 5 J = 1,N
      DIV = A(J,N1)
      A(J,N1) = A(J,N1)
      A(J,N1) = DIV
      DO 6 J = 1,M
      DIV = A(N1,J)
      A(N1,J) = A(N1,J)
      A(N1,J) = DIV
      7 DO 20 K = 1, N1
20 B(K) = A(N,K)/A(N,N-1)
      DO 45 J = 1,M
      SUM = 0.0
      IF (J = N1) 46,43,43
40 IF (r(J)) 41,43,41
41 A(N,J) = 0.0
      DO 42 K = 1,N1
      A(K,J) = A(K,J) - A(K,N1)*B(J)
42 SUM = SUM + A(K,J)*B(K)
      GO TO 45
43 DO 44 K = 1,N1
44 SUM = SUM + A(K,J)*B(K)
45 A(N1,J) = SUM
46 CONTINUE
50 RETURN
      END

```

HESS0004  
HESS0003  
HESS0002  
HESS0001  
HESS00007  
HESS00006  
HESS00005  
HESS00004  
HESS00003  
HESS00002  
HESS00001  
HESS00012  
HESS00013  
HESS00014  
HESS00015  
HESS00016  
HESS00017  
HESS00018  
HESS00019  
HESS00020  
HESS00021  
HESS00022  
HESS00023  
HESS00024  
HESS00025  
HESS00026  
HESS00027  
HESS00028  
HESS00029  
HESS00030  
HESS00031  
HESS00032  
HESS00033  
HESS00034  
HESS00035  
HESS00036  
HESS00037  
HESS00038  
HESS00039  
HESS00040  
HESS00041  
HESS00042  
HESS00043  
HESS00044

```

      FOR GRELIG
      PROGRAM TO CALL QR TRANSFORMATION, MAXIMUM ITER IS 50.
      SUBROUTINE GRELIG(A,M,ROCTR,ROOTI,IPRNT)
      DIMENSION A(3,3),ROCTR(3),ROOTI(3)

      N = M
      IF(IPRNT) 80,81,80
 80   WRITE (6,104)
 81   ZERO = 0.0
 82   JU=1
 177  XNN=0.0
      XL2=0.0
      AA = 0.0
      B = 0.0
      C = 0.0
      DL = 0.0
      RE=0.0
      SIG=0.0
      ITER = 0
 17   IF (JU-2) 15,14,12
 13   IF (IPRNT) 82,83,82
 82   WRITE (6,105)A(1,1)
 83   ROOTR(1) = A(1,1)
      ROOTI(1) = 0.0
 1     RETURN
 14   JU=-1
 12   X = (A(N-1,N-1) - A(N,N))**2
      S = 4.0*A(N,N-1)*A(N-1,N)
      ITER = ITER + 1
      IF (ABS(S/X).GT. 1.0E-8) GO TO 15
 16   IF (ABS(A(N-1,N-1))-ABS(A(N,N))) 32,32,31
 31   E = A(N-1,N-1)
      G = A(N,N)
      GO TO 33
 32   G = A(N-1,N-1)
      E = A(N,N)
 33   F = 0.
      H = 0.
      GO TO 24
 15   S = X + S
      X = A(N-1,N-1) + A(N,N)
      IF (S) 18,19,19
 19   SC=SURT(S)
      F=0.0
      H=0.0
      IF (X) 21,21,22
 21   E=(X-SC)/2.0
      G=(X+SC)/2.0
      GO TO 24
 22   G=(X-SC)/2.0
      E=(X+SC)/2.0
      GO TO 24
 18   F = SURT(-S)/2.0
      E=X/2.0
      G=L
      H=-F
 24   IF (JU) 28,70,70
 70   D = 1.0E-10*(ABS(E) + F)
      IF (ABS(A(N-1,N-2)).GT. D) GO TO 26
 26   IF (IPRNT) 84,85,84
 84   WRITE (6,105)E,F, ITER

```

```

85  WRITE (0,105) U,R
     ROOTR(N) = E
     ROOTI(N) = F
     ROOTR(N-1) = G
     ROOTI(N-1) = H
     N=N-1
     IF(JJ) 1,177,177
26  IF(ABS(A(N,N-1)) .GT. 1.0E-10*ABS(A(N,N))) GO TO 50
29  IF(IPRNT) 86,87,86
86  WRITE (6,105) A(N,N), ZERO, ITER
87  ROOTR(N) = A(N,N)
     ROOTI(N) = 0.0
     N=N-1
     GO TO 177
50  IF(ABS(XNN/A(N,N-1))-1.0)-1.0E-6) 63,63,62
62  IF(ABS(XN2/A(N-1,N-2))-1.0)-1.0E-6) 63,63,700
63  V=ABS(A(N,N-1))-ABS(A(N-1,N-2))
64  IF(V) 67,67,60
66  IF(IPRNT) 88,85,88
88  WRITE (6,107) A(N-1,N-2)
     GO TO 84
87  IF(IPRNT) 89,87,89
89  WRITE (6,107) A(N,N-1)
     GO TO 86
70L IF(ITER .GT. 50) GO TO 63
701 Z1= ((E-AA)**2+(F-B)**2)/(E*E+F*F)
     Z2= ((G-C)**2+(H-DD)**2)/(G*G+H*H)
     IF(Z1-0.25) 51,51,52
     IF(Z2-0.25) 53,53,54
51  R=E*E
     SIG=E+E
     GO TO 60
54  R=E*E
     SIG=E+E
     GO TO 60
52  IF(Z2-0.25) 55,55,001
55  R=G*G
     SIG=G+G
     GO TO 60
501 R = 0.0
     SIG = 0.0
50  X1=N*A(N,N-1)
     X2=N*A(N-1,N-2)
     CALL QRT(A,N,R,SIG,D)
     AA=E
     D=F
     C=G
     U=F
     GO TO 12
104 FORMAT(1X, 9HREAL PART 0X 14HIMAGINARY PART, 26X
     1 13HTAKEN AS ZERO 6X 4HITER //)
105 FORMAT(1X,E15.8,3X,E15.8, 42X 13)
107 FORMAT(50X E13.8)
     END

```

```

GRCN0001
GRCN0002
GRCN0003
GRCN0004
GRCN0005
GRCN0006
GRCN0007
GRCN0008
GRCN0009
GRCN00069
GRCN0070
GRCN0071
GRCN0072
GRCN0073
GRCN0074
GRCN0075
GRCN0076
GRCN0077
GRCN0078
GRCN0079
GRCN0080
GRCN0081
GRCN0082
GRCN0083
GRCN0084
GRCN0085
GRCN0086
GRCN0087
GRCN0088
GRCN0089
GRCN0090
GRCN0091
GRCN0092
GRCN0093
GRCN0094
GRCN0095
GRCN0096
GRCN0097
GRCN0098
GRCN0099
GRCN0100
GRCN0101
GRCN0102
GRCN0103
GRCN0104
GRCN0105
GRCN0106
GRCN0107
GRCN0108
GRCN0109
GRCN0110
GRCN0111
GRCN0112
GRCN0113
GRCN0114

```

```

      FOR GRT
      SUBROUTINE GRT(A,N,R,SIG,D)
      DIMENSION A(3,3), PSI(3), G(J)
      I1 = N - 1
      IA = N - 2
      IP = IA
      IF (N=3) 101,10,60
  60  GO TO J = 3,N1
      J1 = N - J
      IF (ABS(A(J1+1,J1))=0) 10,10,11
  11  IF (ABS(A(J1+1,J1))*A(J1+2,J1+1)*(ABS(A(J1+1,J1+1)+A(J1+2,J1+2)
      1-SIG)+ABS(A(J1+3,J1+2)))/(A(J1+1,J1+1)*(A(J1+1,J1+1)-SIG)+A(
      21+J1+2)*A(J1+2,J1+1)+R))-D) 10,10,12
  12  IP=J1
  13  GO TO J=1,IP
      J1=IP+1
      IF (ABS(A(J1+1,J1))=0) 13,13,14
  14  I6=J1
  15  GO TO I=IP,N1
      IF (I=IP) 16,15,16
  16  G(1)=A(IP,IP)*(A(IP,IP)-SIG)+A(IP,IP+1)*A(IP+1,IP)+R
      G(2)=A(IP+1,IP)*(A(IP,IP)+A(IP+1,IP+1)-SIG)
      G(3)=A(IP+1,IP)*A(IP+2,IP+1)
      A(IP+2,IP)=0.0
  17  GO TO 19
  18  G(1)=A(I,I-1)
      G(2)=A(I+1,I-1)
      IF (I=IA) 17,17,18
  19  G(3)=A(I+2,I-1)
  20  GO TO 19
  21  G(3)=0.0
  22  XK = SIGN(SQRT(G(1)**2 + G(2)**2 + G(3)**2), G(1))
  23  AL=G(1)/XK+1.0
      PSI(1)=G(2)/(G(1)+XK)
      PSI(2)=G(3)/(G(1)+XK)
  24  GO TO 25
  25  AL=2.0
      PSI(1)=0.0
      PSI(2)=0.0
  26  IF (I=1) 20,27,26
  27  IF (I=IP) 29,28,29
  28  A(I,I-1)=-A(I,I-1)
  29  GO TO 27
  30  A(I,I-1)=-XK
  31  GO TO J=I,N
      IF (I=IA) 31,31,32
  32  C=PSI(2)*A(I+2,J)
  33  GO TO 33
  34  E=AL*(A(I,J)+PSI(1)*A(I+1,J)+C)
      A(I,J)=A(I,J)-E
      A(I+1,J)=A(I+1,J)-PSI(1)*E
      IF (I=IA) 34,34,30
  35  A(I+2,J)=A(I+2,J)-PSI(2)*E
  36  CONTINUE
  37  IF (I=IA) 35,35,36
  38  L=I+2
  39  GO TO 37
  40  L=N

```

37 DO 40 J=Iw,L  
IF (I-1A) 38,38,39  
38 C=PSI(2)\*A(J,I+2)  
GO TO 41  
39 C=0.0  
41 E=AL\*(A(J,I)+PSI(1)\*A(J,I+1)+C)  
A(J,I)=A(J,I)-E  
A(J,I+1)=A(J,I+1)-PSI(1)\*E  
IF (I-1A) 42,42,40  
42 A(J,I+2)=A(J,I+2)-PSI(2)\*E  
40 CONTINUE  
IF (I-I+3) 43,43,100  
43 E=AL\*PSI(2)\*A(I+3,I+2)  
A(I+3,I)=-E  
A(I+3,I+1)=-PSI(1)\*E  
A(I+3,I+2)=A(I+3,I+2)-PSI(2)\*E  
100 CONTINUE  
101 RETURN.  
END.

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* FOR UNST1
C NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)
C SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (82).
C CONSIDERATION OF THREE (3) CASES, INVOLVING 30 VALUES.
C SUBROUTINE UNST1(PI,R,H,T0,CK,RI,GAM,OMG,M,N)
C DIMENSION OMG(20,20,3),COMG(20,20,3),A(20,20,3),B(20,20,3),DELO(20
1,20,3),C(20,20,3),D(20,20,3),F(20,20,3),BETA(20,20,3),BETA12(20,20
2,3),F1(4),X(4)
DO 1 J=1,M
DO 1 K=1,N
DO 1 I=1,3
COMG(J,K,I)=0.0
1 CONTINUE
101 FORMAT (20X,6Hhtable of unstable values of the thrust frequency fo
1R equation (82), rad per sec.,//,4X,2HJ,,4X,2HK,,8X,10HCCMEGA (1),
2//)
102 FORMAT (2I5, 1E20.8//)
103 FORMAT (20X,3SHFIRST CASE, LOWER CASE M EQUAL 1.,//)
104 FORMAT (20X,34HSECOND CASE, LOWER CASE M EQUAL 2.,//)
105 FORMAT (20X,33HTHIRD CASE, LOWER CASE M EQUAL 3.,//)
DO 2 J=1,1
DO 2 K=1,N
DO 2 I=1,1
START=1.2
START1=1.
55 X(1)=START*(OMG(J,K,I))
DO 3 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)30,31,30
30 C2=2.***28
IF (B(J,K,I)-C2)300,301,301
31 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 32
300 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
32 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)33,33,34
34 START=START-.1
IF (START)325,325,35
325 COMG(J,K,I)=.33333333
GO 10 2001
35 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(L)=OMG(J,K,I)/(1.-BETA12(J,K,I))
3 X(L+1)=F1(L)
4 X(3)=(X(1)+F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)36,37,36
36 C2=2.***28
IF (B(J,K,I)-C2)360,401,401
DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 38
380 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
38 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))

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59 IF (AUS(J,K,I))=1.39,39,6
F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(3)=(OMG(J,K,I))/(1.-BETA12(J,K,I))
D1=X(3)-F1(3)
IF (AUS(X(3))=1000.)390,394,394
390 IF (AUS(X(3))=100.)392,393,390
392 C1=.001
GO TO 395
393 C1=.01
GO TO 395
394 C1=.1
395 IF (AUS(D1)=C1)5,5,6
5 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF (START1=1000.)4,4,201
201 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF (A(J,K,I)=1.0)330,501,501
330 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (AUS(C(J,K,I)-X(3))=C3)331,331,332
331 COMG(J,K,I)=.88888888
GO TO 2001
332 COMG(J,K,I)=.11111111
GO TO 2001
351 COMG(J,K,I)=.77777777
GO TO 2001
401 COMG(J,K,I)=.99999999
GO TO 2001
5 COMG(J,K,I)=AUS(X(3))
IF (A(J,K,I)=1.)2001,501,501
501 COMG(J,K,I)=.66666666
2001 CONTINUE
< CONTINUE
WRITE(6,101)
WRITE(6,103)
DO 7 J=1,N
DO 7 K=1,N
J1=J-1
K1=K-1
WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,1)
7 CONTINUE
DO 8 J=1,1
DO 8 K=1,N
DO 8 L=1,1
START1=1,2
START1=1,
45 X(1)=START*(OMG(J,K,I))
DO 9 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)=1.)40,41,40
40 C2=C2.*20
IF (L(J,K,I)=C2)400,302,302
41 DEL0(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 42

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400  DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1)))))/TAN(B(J,K,I))
41  C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
42  D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
43  IF(ABS(D(J,K,I))-1.)430,431,44
44  START=START-.1
45  IF(START)425,425,45
425  COMG(J,K,I)=.33333333
46  GO TO 2002
47  F(J,K,I)=PI-ASIN(D(J,K,I))
48  BETA(J,K,I)=(2./PI)*(F(J,K,I))
49  BETA12(J,K,I)=.5*(BETA(J,K,I))
50  F1(L)=(OMG(J,K,I))/(BETA12(J,K,I))
51  X(L+1)=F1(L)
52  X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
53  A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
54  B(J,K,I)=.5*PI*SQRT(A(J,K,I))
55  IF(A(J,K,I)-1.)460,470,46
56  C2=2.***28
57  IF(H(J,K,I)-C2)460,402,402
58  DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.)
59  GO TO 48
460  DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1)))))/TAN(B(J,K,I))
470  C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
480  D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
490  IF(Abs(D(J,K,I))-1.)490,494,494
491  F(J,K,I)=PI-ASIN(D(J,K,I))
492  BETA(J,K,I)=(2./PI)*(F(J,K,I))
493  BETA12(J,K,I)=.5*(BETA(J,K,I))
494  F1(3)=(OMG(J,K,I))/(BETA12(J,K,I))
495  D1=X(3)-F1(3)
496  IF(ABS(X(3))-1000.)490,494,494
497  IF(ABS(X(3))-100.)492,493,493
498  C1=.001
499  GO TO 495
500  C1=.01
501  GO TO 495
502  C1=.1
503  IF(Abs(D1)-C1)11,11,12
504  X(1)=X(2)
505  F1(1)=F1(2)
506  X(2)=X(3)
507  F1(2)=F1(3)
508  START1=START1+1.
509  IF(START1-1000.)10,10,202
510  A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
511  IF(A(J,K,I)-1.0)430,502,502
512  B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
513  C(J,K,I)=SQRT(B(J,K,I))
514  C3=.01
515  IF(Abs(C(J,K,I)-X(3))-C3)431,431,432
516  COMG(J,K,I)=.88888888
517  GO TO 2002
518  COMG(J,K,I)=.11111111
519  GO TO 2002
520  COMG(J,K,I)=.77777777
521  GO TO 2002
522  COMG(J,K,I)=.99999999
523  GO TO 2002
524  COMU(J,K,I)=ABS(X(3))

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502 IF (A(J,K,I)-1.)2002,502,502
COMG(J,K,I)=.066666666
CONTINUE
502 CONTINUE
503 WRITE(6,101)
504 WRITE(6,104)
DO 13 J=1,1
DO 13 K=1,N
J1=J-1
K1=R-1
505 WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,1)
13 CONTINUE
DO 14 J=1,1
DO 14 K=1,N
DO 14 I=1,1
START=.1
START1=1.
506 X(1)=START*(COMG(J,K,I))
DO 15 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)50,51,50
507 C2=2.***28
IF (B(J,K,I)-C2)500,303,303
508 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 52
509 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,1)))
510 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,1))-1.)53,53,54
511 START=START+.1
IF (START-1.0)55,55,525
512 COMG(J,K,I)=.33333333
GO TO 2003
513 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA1(J,K,1)=.5*(BETA(J,K,I))
F1(L)=(OMG(J,K,I))/(1.+BETA1(J,K,I))
514 X(L+1)=F1(L)
515 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)56,57,56
516 C2=2.***28
IF (B(J,K,I)-C2)560,403,403
517 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 58
518 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,1)))
519 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,1))-1.)59,59,18
520 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA1(J,K,1)=.5*(BETA(J,K,I))
F1(3)=(OMG(J,K,I))/(1.+BETA1(J,K,I))
521 D1=X(3)-F1(3)
IF (ABS(X(3))-1000.)590,594,594
522 IF (ABS(X(3))-100.)592,593,593
523 C1=.001

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GO TO 595
593 C1=.01
GO TO 595
594 C1=.1
IF (ABD(U1)-C1)17,17,18
18 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF (START1-100.)16,16,203
203 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF (A(J,K,I)-1.0)530,503,503
530 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(3))-C3)531,531,532
531 COMG(J,K,I)=.88888888
GO TO 2003
532 COMG(J,K,I)=.11111111
GO TO 2003
503 COMG(J,K,I)=.77777777
GO TO 2003
403 COMG(J,K,I)=.99999999
GO TO 2003
17 COMG(J,K,I)=AUS(X(3))
IF (A(J,K,I)-1.)2003,503,503
503 COMG(J,K,I)=.66666666
2003 CONTINUE
14 CONTINUE
WRITE(6,101)
WRITE(6,105)
DO 19 J=1,1
DO 19 K=1,N
J1=J-1
K1=K-1
WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,1)
19 CONTINUE
RETURN.
END

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*1 FOR UNST2
C   NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)
C   SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (83).
C   CONSIDERATION OF ONE (1) CASE, INVOLVING 20 VALUES.
      SUBROUTINE UNST2(PI,R,H,T0,CK,RI,GAM,OMG,M,N)
      DIMENSION OMG(20,20,3),COMG(20,20,3)
101  FORMAT (20X,8UHTABLE OF UNSTABLE VALUES OF THE THRUST FREQUENCY FU
     1R EQUATION (83), RAD PER SEC.,//,4X,2HJ,,4X,2HK,,8X,1UHCOMEGA (1),
     210X,1UHCOMEGA (2),//)
102  FORMAT (2I5, 2E20.8//)
      DO 1 J=1,M
      DO 1 K=1,N
      DO 1 I=1,3
      COMG(J,K,I)=0.0
1    CONTINUE
      DO 2 J=2,M
      DO 2 K=1,1
      DO 2 I=1,2
      COMG(J,K,I)=OMG(J,K,I)
2    CONTINUE
      WRITE (6,101)
      DO 3 J=2,M
      DO 3 K=1,1
      J1=J-1
      K1=K-1
      WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,2)
3    CONTINUE
      RETURN
      END

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*1 FOR UNST3
C NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)
C SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (84).
C CONSIDERATION OF 9 CASES (3 INADMISSIBLE), INVOLVING 120 VALUES.
C SUBROUTINE UNST3(PI,R,H,T0,CK,RI,GAM,OMG,M,N)
C DIMENSION OMG(20,20,3),COMG(20,20,3),A(20,20,3),B(20,20,3),DELO(20
1,20,3),C(20,20,3),D(20,20,3),F(20,20,3),BETA(20,20,3),BETA12(20,20
2,3),F1(4),X(4)
101 FORMAT (20X,8HUNSTABLE OF UNSTABLE VALUES OF THE THRUST FREQUENCY FU
1R EQUATION (84), RAD PER SEC.,//,4X,2HJ,,4X,2HK,,8X,10HCOMEGA (1),
210X,1UHCOMEGA (2),//)
102 FORMAT (2I5, 2E20.8//)
103 FORMAT (10X,78HFIRST CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUA
1L 1, (CASE NOT ADMISSIBLE).///)
104 FORMAT (10X,56HSECOND CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUA
1L 1,//)
105 FORMAT (10X,55HTHIRD CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUA
1L 1,//)
106 FORMAT (10X,50HFOURTH CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUA
1AL 2,//)
107 FORMAT (10X,78HFIFTH CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUA
1L 2, (CASE NOT ADMISSIBLE).///)
108 FORMAT (10X,55HSIXTH CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUA
1L 2,//)
109 FORMAT (10X,57HSEVENTH CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUA
1AL 3,//)
110 FORMAT (10X,56HEIGHTH CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUA
1AL 3,//)
111 FORMAT (10X,78HNINTH CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUA
1L 3, (CASE NOT ADMISSIBLE).///)
1 DO 1 J=1,M
1 DO 1 K=1,N
1 DO 1 I=1,3
1 COMG(J,K,I)=0.0
1 CONTINUE
1 WRITE (6,101)
1 WRITE (6,103)
1 DO 2 J=2,M
1 DO 2 K=1,1
1 DO 2 I=1,2
1 START=.1
1 START1=1.
35 X(1)=START*(OMG(J,K,I))
1 DO 3 L=1,2
1 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
1 B(J,K,I)=.5*PI*SQRT(A(J,K,I))
1 IF(A(J,K,I)-1.)30,31,30
30 C2=2.**28
1 IF(B(J,K,I)-C2)300,301,301
31 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
1 GO TO 32
300 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,I)))
32 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
1 D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
1 IF(ABS(D(J,K,I))-1.)33,33,34
34 START=START+.1
1 IF(START-1.0)35,35,325
325 COMG(J,K,I)=.33333333
1 GO TO 2001

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33 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(L)=(OMG(J,K,I))/(ABS(-1.+BETA(J,K,I)))
3 X(L+1)=F1(L)
4 X(S)=(X(1)+F1(2)-X(2)*F1(1))/(X(1)+F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF(A(J,K,I)-1.)36,37,36
36 C2=2.**28
IF(B(J,K,I)-C2)360,401,401
37 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 38
360 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
38 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF(ABS(D(J,K,I))-1.)39,39,6
39 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(S)=(OMG(J,K,I))/(ABS(-1.+BETA(J,K,I)))
D1=X(S)-F1(S)
IF(ABS(X(S))-1000.)390,394,394
390 IF(ABS(X(S))-100.)392,393,393
392 C1=.001
GO TO 395
393 C1=.01
GO TO 395
394 C1=.1
395 IF(ABS(D1)-C1)5,5,6
0 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF(START1-100.)4,4,201
201 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF(A(J,K,I)-1.0)330,501,501
530 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF(ABS(C(J,K,I)-X(3))-C3)331,331,332
331 COMG(J,K,I)=.88888888
GO TO 2001
332 COMG(J,K,I)=.11111111
GO TO 2001
301 COMG(J,K,I)=.77777777
GO TO 2001
401 COMG(J,K,I)=.99999999
GO TO 2001
5 COMG(J,K,I)=ABS(X(S))
IF(A(J,K,I)-1.)2001,501,501
501 COMG(J,K,I)=.06666666
2001 CONTINUE
2 CONTINUE
WRITE(6,101)
WRITE(6,104)
DO 7 J=2,M
DO 7 K=1,1
J1=J-1
K1=K-1
WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,2)

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```

7      CONTINUE
    DO 8 J=2,M
    DO 8 K=1,1
    DO 8 I=1,2
    START=.6
    START1=1.
45    X(1)=START*(OMG(J,K,I))
    DO 9 L=1,2
    A(J,K,I)=(8.*PI*R*H*T0*(K)/(RI*X(L)*X(L)))
    B(J,K,I)=.5*PI*SQRT(A(J,K,I))
    IF(A(J,K,I)-1.)40,41,40
40    C2=2.**28
    IF(B(J,K,I)-C2)400,302,302
41    DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.)
    GO TO 42
400   DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I)
1))))/TAN(B(J,K,I)))
42    C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
    D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
    IF(ABS(D(J,K,I))-1.)43,43,44
44    START=START-.1
    IF(START)425,425,45
425   OMG(J,K,I)=.33333333
    GO TO 2002
43    F(J,K,I)=PI-ASIN(D(J,K,I))
    BETA(J,K,I)=(2./PI)*(F(J,K,I))
    F1(L)=(OMG(J,K,I))/(ABS(BETA(J,K,I)))
9     X(L+1)=F1(L)
10    X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
    A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
    B(J,K,I)=.5*PI*SQRT(A(J,K,I))
    IF(A(J,K,I)-1.)46,47,46
46    C2=2.**28
    IF(D(J,K,I)-C2)460,402,402
47    DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.)
    GO TO 48
460   DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I)
1))))/TAN(B(J,K,I)))
48    C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
    D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
    IF(ABS(D(J,K,I))-1.)49,49,12
49    F(J,K,I)=PI-ASIN(D(J,K,I))
    BETA(J,K,I)=(2./PI)*(F(J,K,I))
    F1(3)=(OMG(J,K,I))/(ABS(BETA(J,K,I)))
    D1=X(3)-F1(3)
    IF(ABS(X(3))-1000.)490,494,494
490   IF(ABS(X(3))-100.)492,493,493
492   C1=.001
    GO TO 495
493   C1=.01
    GO TO 495
494   C1=.1
495   IF(ABS(D1)-C1)11,11,12
12    X(1)=X(2)
    F1(1)=F1(2)
    X(2)=X(3)
    F1(2)=F1(3)
    START1=START1+1.
    IF(START1-1000.)10,10,202
202   A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
    IF(A(J,K,I)-1.0)430,502,502

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430 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(3))=C3)431,431,432
431 COMG(J,K,I)=.88888888
GO TO 2002
432 COMG(J,K,I)=.11111111
GO TO 2002
302 COMG(J,K,I)=.77777777
GO TO 2002
402 COMG(J,K,I)=.99999999
GO TO 2002
11 COMG(J,K,I)=ABS(X(3))
IF (A(J,K,I)=1.)2002,502,502
502 COMG(J,K,I)=.66666666
2002 CONTINUE
8 CONTINUE
WRITE(6,101)
WRITE(6,105)
DO 13 J=2,M
DO 13 K=1,1
J1=J-1
K1=K-1
WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,2)
13 CONTINUE
DO 14 J=2,M
DO 14 K=1,1
DO 14 I=1,2
START=-1
START1=1.
55 X(1)=START*(OMG(J,K,I))
DO 15 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*(K))/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)=1.)50,51,50
50 C2=2.**28
IF (B(J,K,I)=C2)500,303,303
51 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 52
500 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
52 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))=1.)53,53,54
54 START=START+.1
IF (START-1.0)55,55,525
525 COMG(J,K,I)=.33333333
GO TO 2003
53 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(L)=(OMG(J,K,I))/(ABS(1.-BETA(J,K,I)))
15 X(L+1)=F1(L)
16 X(3)=(X(1)+F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)=1.)56,57,56
56 C2=2.**28
IF (B(J,K,I)=C2)560,403,403
57 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 58
560 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I

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1))))) / TAN(B(J,K,I))
56 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF(ABS(D(J,K,I))-1.)59,59,18
59 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(z./PI)*(F(J,K,I))
F1(3)=(OMG(J,K,I))/(ABS(1.-BETA(J,K,I)))
U1=X(J)-F1(J)
IF(ABS(X(3))-1000.)590,594,594
590 IF(ABS(X(3))-100.)592,593,593
592 C1=.001
GO TO 595
593 C1=.01
GO TO 595
594 C1=.1
595 IF(ABS(D1)-C1)17,17,18
18 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF(START1-100.)16,16,203
203 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF(A(J,K,I)-1.0)530,503,503
530 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF(ABS(C(J,K,I)-X(3))-C3)531,531,532
531 COMG(J,K,I)=.88888888
GO TO 2003
532 COMG(J,K,I)=.11111111
GO TO 2003
303 COMG(J,K,I)=.77777777
GO TO 2003
403 COMG(J,K,I)=.99999999
GO TO 2003
17 COMG(J,K,I)=ABS(X(3))
IF(A(J,K,I)-1.)2003,503,503
503 COMG(J,K,I)=.66666666
2003 CONTINUE
14 CONTINUE
WRITE(6,101)
WRITE(6,106)
DO 19 J=2,M
DO 19 K=1,1
J1=J-1
K1=K-1
WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,2)
19 CONTINUE
WRITE(6,101)
WRITE(6,107)
WRITE(6,101)
WRITE(6,108)
DO 20 J=2,M
DO 20 K=1,1
DO 20 I=1,2
COMG(J,K,I)=OMG(J,K,I)
CONTINUE
DO 21 J=2,M
DO 21 K=1,1
J1=J-1

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      K1=K-1
      WRITE (6,102) J1,K1,(OMG(J,K,I),I=1,2)
21   CONTINUE
      DO 22 J=2,M
      DO 22 K=1,1
      DO 22 I=1,2
      START=.6
      START1=1.
65   X(1)=START*(OMG(J,K,I))
      DO 23 L=1,2
      A(J,K,I)=(8.*PI*R*H*TO*CK)/(RI*X(L)*X(L))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF(A(J,K,I)-1.)60,61,60
60   C2=2.**28
      IF(B(J,K,I)-C2)600,304,304
61   DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 62
600  DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,I)))
62   C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF(ABS(D(J,K,I))-1.)63,63,64
63   START=START-.1
      IF(START)625,625,65
625  OMG(J,K,I)=.33333333
      GO TO 2004
63   F(J,K,I)=PI-ASIN(D(J,K,I))
      BETA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(L)=(OMG(J,K,I))/(ABS(-1.*(BETA(J,K,I))))
23   X(L+1)=F1(L)
24   X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
      A(J,K,I)=(8.*PI*R*H*TO*CK)/(RI*X(3)*X(3))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF(A(J,K,I)-1.)66,67,66
66   C2=2.**28
      IF(B(J,K,I)-C2)660,404,404
67   DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 68
660  DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,I)))
68   C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF(ABS(D(J,K,I))-1.)69,69,26
69   F(J,K,I)=PI-ASIN(D(J,K,I))
      BETA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(S)=(OMG(J,K,I))/(ABS(-1.*(BETA(J,K,I))))
      D1=X(S)-F1(S)
      IF(ABS(X(S))-1000.)690,694,694
690  IF(ABS(X(S))-100.)692,693,693
692  C1=.001
      GO TO 695
693  C1=.1
      GO TO 695
694  C1=.1
695  IF(ABS(D1)-C1)25,25,26
26   X(1)=X(2)
      F1(1)=F1(2)
      X(2)=X(3)
      F1(2)=F1(3)
      START1=START1+1.
      IF(START1-1000.)24,24,204

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204 A(J,K,I)=(8.*PI*R*H*T0*(K))/(R*I*X(3)*X(3))
IF(A(J,K,I)-1.0)630,504,504
630 B(J,K,I)=(8.*PI*R*H*T0*(K))/(R*I)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF(AB,(C(J,K,I)-X(3))-C3)631,631,632
631 COMG(J,K,I)=.88888888
GO TO 2004
632 COMG(J,K,I)=.11111111
GO TO 2004
304 COMG(J,K,I)=.77777777
GO TO 2004
404 COMG(J,K,I)=.99999999
GO TO 2004
25 COMG(J,K,I)=ABS(X(3))
IF(A(J,K,I)-1.)2004,504,504
504 COMG(J,K,I)=.66666666
2004 CONTINUE
22 CONTINUE
      WRITE(6,101)
      WRITE(6,109)
DO 27 J=2,M
DO 27 K=1,1
J1=J-1
K1=K-1
      WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,2)
27 CONTINUE
DO 28 J=2,M
DO 28 K=1,1
DO 28 I=1,2
COMG(J,K,I)=UMG(J,K,I)
28 CONTINUE
      WRITE(6,101)
      WRITE(6,110)
DO 29 J=2,M
DO 29 K=1,1
J1=J-1
K1=K-1
      WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,2)
29 CONTINUE
      WRITE(6,101)
      WRITE(6,111)
RETURN
END

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* 1. OR UNST4
C   NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)
C   SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (85).
C   CONSIDERATION OF 9 CASES (3 INADMISSIBLE), INVOLVING 120 VALUES.
C   SUBROUTINE UNST4(PI,R,H,T0,CK,RI,GAM,OMG,M,N)
C   DIMENSION OMG(20,20,3),COMG(20,20,3),A(20,20,3),B(20,20,3),DEL0(20
1 1,20,3),C(20,20,3),D(20,20,3),F(20,20,3),BETA(20,20,3),BETA12(20,20
2 2,3),F1(4),X(4)
101  FORMAT (20X,80HTABLE OF UNSTABLE VALUES OF THE THRUST FREQUENCY FU
1R EQUATION (85), RAD PER SEC.,//,4X,2HJ,,4X,2HK,,8X,10HCOMEGA (1),
210X,1UHCOMEGA (2),//)
102  FORMAT (2I5, 2E20.8//)
103  FORMAT (10X,78HFIRST CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUA
1L 1, (CASE NOT ADMISSIBLE).///)
104  FORMAT (10X,56HSECOND CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUA
1L 1,//)
105  FORMAT (10X,55HTHIRD CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUA
1L 1,//)
106  FORMAT (10X,56HFOURTH CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUA
1L 2,//)
107  FORMAT (10X,73HFIFTH CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUA
1L 2, (CASE NOT ADMISSIBLE).///)
108  FORMAT (10X,55HSIXTH CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUA
1L 2,//)
109  FORMAT (10X,57HSEVENTH CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUA
1L 3,//)
110  FORMAT (10X,56HEIGHTH CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUA
1L 3,//)
111  FORMAT (10X,70HNINTH CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUA
1L 3, (CASE NOT ADMISSIBLE).///)
DO 1 J=1,M
DO 1 K=1,N
DO 1 I=1,3
COMG(J,K,I)=0.0
1  CONTINUE
DO 2 J=2,M
DO 2 K=1,1
DO 2 I=1,2
COMG(J,K,I)=OMG(J,K,I)
2  CONTINUE
WRITE (6,101)
WRITE (6,103)
WRITE (6,101)
WRITE (6,104)
DO 3 J=2,M
DO 3 K=1,1
J1=J-1
KICK=1
WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,2)
3  CONTINUE
DO 4 J=2,M
DO 4 K=1,1
DO 4 I=1,2
COMG(J,K,I)=J*(OMG(J,K,I))
4  CONTINUE
WRITE (6,101)
WRITE (6,105)
DO 5 J=2,M
DO 5 K=1,1
J1=J-1

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```

K1=K-1
      WRITE (6,102) J1,K1,(OMG(J,K,I),I=1,2)
5      CONTINUE
      DO 6 J=2,M
      DO 6 K=1,1
      DO 6 I=1,2
      OMG(J,K,I)=OMG(J,K,I)
6      CONTINUE
      WRITE (6,101)
      WRITE (6,106)
      DO 7 J=2,M
      DO 7 K=1,1
      J1=J-1
      K1=K-1
      WRITE (6,102) J1,K1,(OMG(J,K,I),I=1,2)
7      CONTINUE
      WRITE (6,101)
      WRITE (6,107)
      DO 8 J=2,M
      DO 8 K=1,1
      DO 8 I=1,2
      STARTI=1
      STARTI=1.
35     X(1)=START*(OMG(J,K,I))
      DO 9 L=1,2
      A(J,K,I)=(8.*PI*R*H*T0*(K))/(R*I*X(L)*X(L))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF(A(J,K,I)-1.)30,31,30
30     C2=2.***28
      IF(8.(J,K,I)-C2)300,301,301
31     DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 32
300    DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
32     C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF(ABS(D(J,K,I))-1.)33,33,34
34     START=START+.1
      IF(START-1.0)35,35,325
325    OMG(J,K,I)=.33333333
      GO TO 2001
33     F(J,K,I)=ASIN(D(J,K,I))
      BETA(J,K,I)=(Z./PI)*(F(J,K,I))
      F1(L)=(OMG(J,K,I))/(ABS(1.+BETA(J,K,I)))
9      X(L+1)=F1(L)
10     X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
      A(J,K,I)=(8.*PI*R*H*T0*(K))/(R*I*X(3)*X(3))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF(A(J,K,I)-1.)36,37,36
36     C2=2.***28
      IF(1.(J,K,I)-C2)360,401,401
37     DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 38
360    DELO(J,K,I)=1.+((PI*((A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
38     C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF(ABS(D(J,K,I))-1.)39,39,12
39     F(J,K,I)=ASIN(D(J,K,I))
      BETA(J,K,I)=(Z./PI)*(F(J,K,I))
      F1(3)=(OMG(J,K,I))/(ABS(1.+BETA(J,K,I)))

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```

J1=J-1
IF (ABS(X(3))-1000.)390,394,394
IF (ABS(X(3))-100.)392,393,393
C1=.001
GO TO 395
C1=.01
GO TO 395
C1=.1
395 IF (ABS(D1)-C1)11,11,12
12 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF (START1-100.)10,10,201
201 A(J,K,I)=(8.*PI*R*H*T0*(K)/(K*X(3)*X(3)))
IF (A(J,K,I)-1.0)330,501,501
330 B(J,K,I)=(8.*PI*R*H*T0*(K)/(K))
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(3))-C3)331,331,332
331 COMG(J,K,I)=.88888888
GO TO 2001
332 COMG(J,K,I)=.11111111
GO TO 2001
301 COMG(J,K,I)=.77777777
GO TO 2001
401 COMG(J,K,I)=.99999999
GO TO 2001
11 COMG(J,K,I)=ABS(X(3))
IF (A(J,K,I)-1.)2001,501,501
501 COMG(J,K,I)=.06666666
2001 CONTINUE
0 CONTINUE
WRITE(6,101)
WRITE(6,108)
DO 13 J=2,M
DO 13 K=1,1
J1=J-1
K1=K-1
WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,2)
13 CONTINUE
DO 14 J=2,M
DO 14 K=1,1
DO 14 I=1,2
COMG(J,K,I)=.5*(OMG(J,K,I))
14 CONTINUE
WRITE(6,101)
WRITE(6,109)
DO 15 J=2,M
DO 15 K=1,1
J1=J-1
K1=K-1
WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,2)
15 CONTINUE
DO 16 J=2,M
DO 16 K=1,1
DO 16 I=1,2
START1=1
START1=1.
40 X(1)=START*(OMG(J,K,I))

```

```

JC 17 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)40,41,40
C2=2.**28
IF (B(J,K,I)-C2)400,302,302
41 DELO(J,K,I)=1.+ (PI*PI*GAM*GAM)/64.
GO TO 42
400 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1)))))/TAN(B(J,K,I))
42 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))/SIN(B(J,K,I))
IF (ABS(D(J,K,I))-1.)43,43,44
44 START=START+.1
IF (START-1.0)45,45,425
425 COMG(J,K,I)=.33333333
GO TO 2002
45 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(z./PI)*(F(J,K,I))
F1(L)=(OMG(J,K,I))/(ABS(1.+BETA(J,K,I)))
17 X(L+1)=F1(L)
18 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)46,47,46
46 C2=2.**28
IF (B(J,K,I)-C2)460,402,402
47 DELO(J,K,I)=1.+ (PI*PI*GAM*GAM)/64.
GO TO 48
400 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1)))))/TAN(B(J,K,I))
48 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))/SIN(B(J,K,I))
IF (ABS(D(J,K,I))-1.)49,49,20
49 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(z./PI)*(F(J,K,I))
F1(3)=(OMG(J,K,I))/(ABS(1.+BETA(J,K,I)))
D1=X(3)-F1(3)
IF (ABS(X(3))-1000.)490,494,494
490 IF (ABS(X(3))-100.)492,493,493
492 C1=.001
GO TO 495
493 C1=.01
GO TO 495
494 C1=.1
495 IF (ABS(D1)-C1)19,19,20
20 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF (START1-100.)18,18,202
202 A(J,K,I)=(8.*PI*R*H*T0*(K))/(RI*X(3)*X(3))
IF (A(J,K,I)-1.0)430,502,502
430 B(J,K,I)=(8.*PI*R*H*T0*(K))/(RI)
C(J,K,I)=SQRT(R(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(3))-C3)431,431,432
431 COMG(J,K,I)=.88888888
GO TO 2002
432 COMG(J,K,I)=.11111111

```

60 TU 2002  
302 COMG(J,K,I)=.77777777  
60 TU 2002  
402 COMG(J,K,I)=.99999999  
60 TU 2002  
49 COMG(J,K,I)=ABS(X(3))  
IF (A(J,K,I)-1.)2002,502,502  
502 COMG(J,K,I)=.06666666  
2002 CONTINUE  
16 CONTINUE  
WRITE (6,101)  
WRITE (6,110)  
DO 21 J=2,M  
DO 21 K=1,1  
J1=J-1  
K1=K-1  
WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,2)  
21 CONTINUE  
WRITE (6,101)  
WRITE (6,111)  
RETURN  
END

```

• 1 FOR UNSTS
C NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)
C SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (86).
C CONSIDERATION OF THREE (3) CASES, INVOLVING 60 VALUES.
C SUBROUTINE UNSTS (PI,R,H,T0,CK,RI,GAM,OMG,M,N)
C DIMENSION OMG(20,20,3),COMG(20,20,3),A(20,20,3),B(20,20,3),DELO(20
101 1,20,3),C(20,20,3),D(20,20,3),F(20,20,3),BETA(20,20,3),F1(4),X(4)
FORMAT (20X,8UHTABLE OF UNSTABLE VALUES OF THE THRUST FREQUENCY FU
1R EQUATION (86), RAD PER SEC.,//,4X,2HJ,,4X,2HK,,8X,10HCOMEGA (1),
210X,10HCOMEGA (2),//)
102 FORMAT (2I5, 2E20.8//)
103 FORMAT (20X,33HFIRST CASE, LOWER CASE M EQUAL 1.,//)
104 FORMAT (20X,34HSECOND CASE, LOWER CASE M EQUAL 2.,//)
105 FORMAT (20X,33HTHIRD CASE, LOWER CASE M EQUAL 3.,//)
DO 1 J=1,M
DO 1 K=1,N
DO 1 I=1,3
COMG(J,K,I)=0.0
1 CONTINUE
DO 2 J=2,M
DO 2 K=1,1
DO 2 I=1,2
START=-.1
STARTI=1.
55 X(1)=START*(UMG(J,K,I))
DO 3 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)=1.)30,31,30
50 C2=2.*28
IF (B(J,K,I)=C2)300,301,301
31 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 32
300 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
32 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))=1.)33,33,34
54 STARTESTART+.1
IF (START=1.0)35,35,325
325 COMG(J,K,I)=.33333333
GO TO 2001
53 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(L)=(OMG(J,K,I))/(2.-BETA(J,K,I))
5 X(L+1)=F1(L)
4 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)=1.)36,37,36
50 C2=2.*28
IF (B(J,K,I)=C2)360,401,401
37 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 38
300 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
38 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))=1.)39,39,36
39 F(J,K,I)=ASIN(D(J,K,I))

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F1(3)=OMG(J,K,I))/(2.-BETA(J,K,I))
J1=X(3)-F1(3)
IF (ABS(X(3))-1000.)390,394,394
IF (ABS(X(3))-100.)392,393,393
C1=.001
GO TO 395
393 C1=.01
GO TO 395
394 C1=.1
395 IF (ABS(D1)-C1)5,5,6
      X(1)=X(2)
      F1(1)=F1(2)
      X(2)=X(3)
      F1(2)=F1(3)
      START1=START1+1.
      IF (START1-1UU.)4,4,201
<01 A(J,K,I)=(8.*PI*R*H*T0*(K))/(R1*X(3)*X(3))
      IF (A(J,K,I)-1.0)330,501,501
500 B(J,K,I)=(8.*PI*R*H*T0*(K))/(R1)
      C(J,K,I)=SQRT(B(J,K,I))
      C3=.01
      IF (ABS(C(J,K,I)-X(3))-C3)331,331,332
531 COMG(J,K,I)=.88888888
      GO TO 2001
532 COMG(J,K,I)=.11111111
      GO TO 2001
501 COMG(J,K,I)=.77777777
      GO TO 2001
401 COMG(J,K,I)=.99999999
      GO TO 2001
5 COMG(J,K,I)=ABS(X(3))
      IF (A(J,K,I)-1.)2001,501,501
501 COMG(J,K,I)=.06666666
2001 CONTINUE
2 CONTINUE
      WRITE(6,101)
      WRITE(6,103)
      DO 7 J=2,M
      DO 7 K=1,1
      J1=J-1
      K1=K-1
      WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,2)
    / CONTINUE
      DO 8 J=2,M
      DO 8 K=1,1
      DO 8 L=1,2
      START1=0
      START1=1.
      X(1)=START*(OMG(J,K,I))
      DO 9 L=1,2
      A(J,K,I)=(8.*PI*R*H*T0*(K))/(R1*X(L)*X(L))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF (A(J,K,I)-1.)40,41,40
40 C2=2.**28
      IF (A(J,K,I)-C2)400,302,302
41 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
      GO TO 42
400 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(10.*((1.-(A(J,K,I
      1))))/TAN(B(J,K,I)))
42 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))

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44 IF (ABS(D(J,K,I))-1.)43,43,44
START1=START-.1
425 IF (START)425,425,45
CUMU(J,K,I)=.33333333
GO TO 2002
45 F(J,K,I)=PI-ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(L)=(OMG(J,K,I))/(BETA(J,K,I))
9 X(L+1)=F1(L)
10 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)46,47,46
46 C2=.4*28
IF (L(J,K,I)-C2)460,402,402
47 DEL0(J,K,I)=1.+((PI*PI*GAM*GAM)/64.)
GO TO 48
480 DEL0(J,K,I)=1.+((P1*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1)))))/TAN(B(J,K,I))
48 C(J,K,I)=SQRT(ABS(DEL0(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)49,49,12
49 F(J,K,I)=PI-ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(3)=(OMG(J,K,I))/(BETA(J,K,I))
D1=X(3)-F1(3)
IF (ABS(X(3))-1000.)490,494,494
490 IF (ABS(X(3))-100.)492,493,493
492 C1=.001
GO TO 495
493 C1=.01
GO TO 495
494 C1=.1
495 IF (ABS(D1)-C1)11,11,12
12 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF (START1-1000.)10,10,202
202 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF (A(J,K,I)-1.0)430,502,502
430 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(3))-C3)431,431,432
431 CUMU(J,K,I)=.88888888
GO TO 2002
432 CUMG(J,K,I)=.11111111
GO TO 2002
302 CUMG(J,K,I)=.77777777
GO TO 2002
402 CUMU(J,K,I)=.99999999
GO TO 2002
11 CUMG(J,K,I)=ABS(X(3))
IF (A(J,K,I)-1.)2002,502,502
2002 CUMU(J,K,I)=.66666666
CONTINUE
8 CONTINUE
WRITE (6,101)
WRITE (6,104)

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      DO 13 J=2,M
      DO 13 K=1,1
      J1=J-1
      K1=K-1
      WRITE(6,102) J1,K1,(CONG(J,K,I),I=1,2)
      CONTINUE
      DO 14 J=2,M
      DO 14 K=1,1
      DO 14 I=1,2
      START=.1
      START1=1.
55   X(1)=START*(OMG(J,K,I))
      DO 15 L=1,2
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(KI*X(L)*X(L))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF (A(J,K,I)-1.)50,51,50
50    C2=2.**28
      IF (B(J,K,I)-C2)500,303,303
51    DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 52
500   DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,I)))
52    C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF (ABS(D(J,K,I))-1.)53,53,54
54    START=START+.1
      IF (START-1.0)55,55,525
525   CONG(J,K,I)=.33333333
      GO TO 2003
55   F(J,K,I)=ASIN(D(J,K,I))
      BETA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(L)=(OMG(J,K,I))/(2.+BETA(J,K,I))
      X(L+1)=F1(L)
15   X(3)=(X(1)+F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(KI*X(3)*X(3))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF (A(J,K,I)-1.)56,57,56
56    C2=2.**28
      IF (B(J,K,I)-C2)560,403,403
57    DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 58
560   DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,I)))
58    C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF (ABS(D(J,K,I))-1.)59,59,18
59    F(J,K,I)=ASIN(D(J,K,I))
      BETA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(3)=(OMG(J,K,I))/(2.+BETA(J,K,I))
      D1=X(3)-F1(3)
      IF (ABS(X(3))-1000.)590,594,594
590   IF (ABS(X(3))-100.)592,593,593
592   C1=.001
      GO TO 595
593   C1=.01
      GO TO 595
      C1=.1
595   IF (ABS(D1)-C1)17,17,18
18    X(1)=X(2)
      F1(1)=F1(2)
      X(2)=X(3)

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```

F1(2)=F1(3)
START1=START1+1.
IF (START1-100.)16,16,203
203 A(J,K,I)=(8.*PI*R*H*T0*(K))/(RI*X(J)*X(3))
530 IF (A(J,K,I)-1.0)530,503,503
503 B(J,K,I)=(8.*PI*R*H*T0*(K))/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(3))-C3)531,531,532
531 COMG(J,K,I)=.888888888
GO TO 2003
532 COMG(J,K,I)=.111111111
GO TO 2003
503 COMG(J,K,I)=.777777777
GO TO 2003
403 COMG(J,K,I)=.999999999
GO TO 2003
17 COMG(J,K,I)=ABS(X(3))
IF (A(J,K,I)-1.)2003,503,503
503 COMG(J,K,I)=.066666666
CONTINUE
14 CONTINUE
WRITE (6,101)
WRITE (6,105)
DO 19 J=2,M
DO 19 K=1,1
J1=J-1
K1=K-1
WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,2)
19 CONTINUE
RETURN
END

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41 FOR UNSTO
C NASA CONTRACT NASB-11255 (LONGITUDINAL VIBRATION RESEARCH)
C SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (87).
C CONSIDERATION OF THREE (3) CASES, INVOLVING 900 VALUES.
C SUBROUTINE UNSTO (PI,R,H,TO,LK,RI,GAM,OMG,M,N)
C DIMENSION OMG(20,20,3),COMG(20,20,3),A(20,20,3),B(20,20,3),DELU(20
10 20,3),C(20,20,3),D(20,20,3),F(20,20,3),BETA(20,20,3),BETA12(20,20
20,3),F1(4),X(4)
101 FORMAT (20X,8UHTABLE OF UNSTABLE VALUES OF THE THRUST FREQUENCY FO
1R EQUATION (87), RAD PER SEC.,//,4X,2HJ,,4X,2HK,,8X,10HCOMEGA (1),
210X,10HCOMEGA (2),10X,10HCOMEGA (3)//)
102 FORMAT (2I5, 3E20.8//)
103 FORMAT (20X,33HFIRST CASE, LOWER CASE M EQUAL 1.,//)
104 FORMAT (20X,34HSECOND CASE, LOWER CASE M EQUAL 2.,//)
105 FORMAT (20X,33HTHIRD CASE, LOWER CASE M EQUAL 3.,//)
DO 1 J=1,M
DO 1 K=1,N
DO 1 I=1,3
COMG(J,K,I)=0.0
1 CONTINUE
DO 2 J=2,M
DO 2 K=2,N
DO 2 I=1,3
START1=.1
START1=1.
35 X(1)=START*(OMG(J,K,I))
DO 3 L=1,2
A(J,K,I)=(8.*PI*R*H*TO*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)30,31,30
50 C2=L.***28
IF (L(J,K,I)-C2)300,301,301
51 DELU(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 32
500 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
52 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ADS(D(J,K,I))-1.)33,33,34
54 START=START+.1
IF (START-1.0)35,35,325
525 COMG(J,K,I)=.33333333
GO TO 2001
55 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(L)=OMG(J,K,I)/(1.-BETA12(J,K,I))
5 X(L+1)=F1(L)
4 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*TO*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)36,37,36
50 C2=L.***28
IF (L(J,K,I)-C2)360,401,401
51 DELU(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
52 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))

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519 IF (ABS(D(J,K+1))-1.)39,39+6
F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA1C(J,K,I)=.5*(BETA(J,K,I))
F1(3)=COMG(J,K,I)/(1.-BETA1C(J,K,I))
D1=X(J)-F1(3)
IF (ABS(X(3))-1000.)390,394,394
390 IF (ABS(X(3))-100.)392,393,393
392 C1=.001
GO TO 395
393 C1=.01
GO TO 395
394 C1=.1
395 IF (ABS(D1)-C1)5,5,6
6 X(1)=A(Z)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF (START1-100.)4,4,201
201 A(J,K,I)=(8.*PI*R*H*T0*(K))/(RI*X(3)*X(3))
IF (A(J,K,I)-1.0)330,501,501
330 B(J,K,I)=(8.*PI*R*H*T0*(K))/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(3))-C3)331,331,332
331 COMG(J,K,I)=.88888888
GO TO 2001
332 COMG(J,K,I)=.11111111
GO TO 2001
301 COMG(J,K,I)=.77777777
GO TO 2001
401 COMG(J,K,I)=.99999999
GO TO 2001
5 COMG(J,K,I)=ABS(X(3))
IF (A(J,K,I)-1.)2001,501,501
501 COMG(J,K,I)=.66666666
2001 CONTINUE
2 CONTINUE
WRITE(6,101)
WRITE(6,103)
DO 7 J=2,M
DO 7 K=2,N
J1=J-1
K1=K-1
WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,3)
7 CONTINUE
DO 8 J=2,M
DO 8 K=2,N
DO 8 I=1,3
START1=1.
START1=1.
45 X(1)=START*(COMG(J,K,I))
DO 9 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*(K))/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)40,41,40
40 C2=2.**28
IF (D(J,K,I)-C2)400,302,302
302 DEL0(J,K,I)=1.+((PI*PI*GAM*GAM)/64.)
GO TO 42

```

```

400  DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I)
1))))/TAN(B(J,K,I))
42   C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)43,43,44
44   START=START-.1
IF (START)425,425,45
425  COMG(J,K,I)=.53333333
GO TU 2002
43   F(J,K,I)=PI-ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(L)=(OMG(J,K,I))/(BETA12(J,K,I))
X(L+1)=F1(L)
10   X(S)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)46,47,46
46   C2=2.***28
IF (L(J,K,I)-C2)460,402,402
47   DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TU 48
480  DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
48   C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)49,49,12
49   F(J,K,I)=PI-ASIN(D(J,K,I))
BLTA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(S)=(OMG(J,K,I))/(BETA12(J,K,I))
D1=X(S)-F1(S)
IF (ABS(X(S))-1000.)490,494,494
490  IF (ABS(X(S))-100.)492,493,493
492  C1=.001
GO TU 495
493  C1=.01
GO TU 495
494  C1=.1
495  IF (ABS(D1)-(C1))11,11,12
12   X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF (START1-1000.)10,10,202
202  A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF (A(J,K,I)-1.0)430,502,502
430  B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(S))-.3)431,431,432
431  COMG(J,K,I)=.088888888
GO TU 2002
432  COMG(J,K,I)=.11111111
GO TU 2002
432  COMG(J,K,I)=.77777777
GO TU 2002
432  COMG(J,K,I)=.99999999
GO TU 2002
11   COMG(J,K,I)=ABS(X(S))

```

```

IF (.(<J,K,1)-1.)2002,502,502
502 COMG(J,K,1)=.66666666
CONTINUE
CONTINUE
WRITE(6,101)
WRITE(6,104)
DO 13 J=2,M
DO 13 K=2,N
JJ=J-1
K1=K-1
WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,3)
13 CONTINUE
DO 14 J=2,M
DO 14 K=2,N
DO 14 I=1,3
START=.1
START1=.1
55 X(1)=START*(OMG(J,K,I))
DO 15 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*(K))/(KI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)50,51,50
50 C2=2.***28
IF (E(J,K,I)-C2)500,303,303
51 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 52
500 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1)))))/TAN(B(J,K,I))
52 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)53,53,54
54 START=START+.1
IF (START-1.0)55,55,525
525 COMG(J,K,1)=.33333333
GO TO 2003
55 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(L)=(OMG(J,K,I))/(1.+BETA12(J,K,I))
15 X(L+1)=F1(L)
16 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(KI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (E(J,K,I)-1.)56,57,56
56 C2=2.***28
IF (E(J,K,I)-C2)560,403,403
57 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 58
560 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1)))))/TAN(B(J,K,I))
58 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)59,59,18
59 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(3)=(OMG(J,K,I))/(1.+BETA12(J,K,I))
D1=X(3)-F1(3)
IF (ABS(X(3))-1000.)590,594,594
590 IF (ABS(X(3))-100.)592,593,593
592 C1=.001

```

```

593 GO TO 595
      C1=.01
      GO TO 595
594      C1=.1
75 18 IF (ABS(J)-C1)17,17,18
      X(1)=A(2)
      F1(1)=F1(2)
      X(2)=A(3)
      F1(2)=F1(3)
      START1=START1+1.
      IF (START1-100.)16,16,203
203  A(J,K,I)=(8.*PI*R*H*T0*CK)/(KI*X(3)*X(3))
      IF (A(J,K,I)-1.0)530,503,503
530  B(J,K,I)=(8.*PI*R*H*T0*CK)/(KI)
      C(J,K,I)=SQRT(B(J,K,I))
      C3=.01
      IF (ABS(C(J,K,I))-X(3))=C3)531,531,532
531  COMG(J,K,I)=.88888888
      GO TO 2003
532  COMG(J,K,I)=.11111111
      GO TO 2003
503  COMG(J,K,I)=.77777777
      GO TO 2003
403  COMG(J,K,I)=.99999999
      GO TO 2003
17   COMG(J,K,I)=ABS(X(3))
      IF (A(J,K,I)-1.)2003,503,503
503  COMG(J,K,I)=.06666666
2003 CONTINUE
14   CONTINUE
      WRITE(6,101)
      WRITE(6,105)
      DO 19 J=2,M
      DO 19 K=2,N
      J1=J-1
      K1=K-1
      WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,3)
19   CONTINUE
      RETURN
      END

```

101. FOR NAFREQ

COMMON L,S,U,V,W,PI,M,N,OMG(20,20,3),R,H,T,O,CK,R1,GAM  
NASA CONTRACT NASR-11255 (LONGITUDINAL VIBRATION RESEARCH)  
FORTRAN IV COMPUTER PROGRAM FOR THE EVALUATION OF NATURAL  
FREQUENCIES (OMG) AND UNSTABLE VALUES OF THE THRUST FREQUENCY  
(COMG) FOR A SIMPLY-SUPPORTED, CIRCULAR CYLINDRICAL SHELL.

REAL L

1 WRITE (6,100)

100 FORMAT (1H1,20X,31HLEGEND OF TERMS USED IN PROGRAM,/,5X,30HH ----  
1HALF LENGTH OF CYLINDER,/,5X,25HR ---- RADIUS OF CYLINDER,/,5X,33H  
2T THICKNESS OF CYLINDER WALL,/,5X,40HRHO -- MASS DENSITY OF C  
3YLINDER MATERIAL,/,5X,38HE ---- YOUNGS MODULUS FOR THE MATERIAL,/,  
45X,21HV ---- POISSONS RATIO,/,5X,26HW ---- REFERENCE FREQUENCY,/,5  
5X,38HM ---- NUMBER OF AXIAL VARIATION TERMS,/,5X,39HN ---- NUMBER  
6OF RADIAL VARIATION TERMS,/,5X,30HJ,K -- SUBSCRIPTS OF THE ARRAY,/  
7,5X,34HOMG(J,K,1) --- NATURAL FREQUENCY 1,/,5X,34HOMG(J,K,2) --- N  
8ATURAL FREQUENCY 2,/,5X,34HOMG(J,K,3) --- NATURAL FREQUENCY 3,/,5X  
9,20H10 --- CONSTANT THRUST FORCE,/,5X,38HGAM -- VARIABLE THRUST/CO  
INSTANT THRUST,/,5X,48HCOMG -- CAPITAL OMEGA, INSTABLE SEARCH FREQU  
2ENCY,/,5X,39HUCOMG -- DELTA CAPITAL OMEGA, INCREMENT,/,5X,20HK--C  
30NTROL CONSTANT)

2 READ (5,102) H,R,T,RHO,E,V,W

102 FORMAT (7F10.5)

3 READ (5,103) M,N,T0,GAM,COMG,DCOMG,CK

103 FORMAT (2I5,5E10.5)

4 WRITE (6,104) H,R,T,RHO,W,E,V,M,N,T0,GAM,COMG,DCOMG,CK

104 FORMAT (1H1,10X,62HUNSTABLE VALUES OF THE THRUST FREQUENCY (COMG) FO  
1R THE CYLINDER,/,5X,14HHALF LENGTH = ,3PE15.5,10X,9HRADIUS = ,3PE  
215.5,10X,12HTHICKNESS = ,1PE15.5,/,3X,15HMASS DENSITY = ,E15.8,9X  
3,22HREFERENCE FREQUENCY = ,E15.5,/,3X,17HYOUNGS MODULUS = ,1PE15.  
45,7X,17HPOISSONS RATIO = ,E15.5,/,3X,34HNUMBER OF AXIAL VARIATION  
5 TERMS = ,15,10X,35HNUMBER OF RADIAL VARIATION TERMS = ,15,/,3X,2  
62HCONSTANT THRUST, T0 = ,1PE15.5,3X,6HGAM = ,E15.5,3X,21HCAPITAL O  
7MEGA,COMG = ,E15.5,/,3X,28HDELTA CAPITAL OMEGA,DCOMG = ,E15.5,3X,  
824HCONTROL CONSTANT K,CK = ,E15.5,/,)

P1=3.141592654

L=H/R

S=T/H

U=RHO\*H\*H\*W\*W/E

CALL NAFREQ (L,S,U,V,W,PI,M,N,OMG)

5 WRITE (6,105)

105 FORMAT (20X,41HTABLE OF NATURAL FREQUENCIES, RAD PER SEC,/,4X,2H0

1,0,4X,2HK,,8X,9HOMEZA (1),11X,9HOMEZA (2),10X,9HOMEZA (3),/)

106 FORMAT (2I5,3E20.8//)

DO 6 J=1,M

DO 6 K=1,N

J1=J-1

K1=K-1

6 WRITE (6,106) J1,K1,(OMG(J,K,I),I=1,3)

RMEZ,\*H\*2.\*P1\*R\*T\*RHO

RIFRM\* (.5\*R\*R+.333\*H\*H)\*386.

CALL CHAIN(2)

GO TO 2

END

```

• 141 FOR UNST7
C      NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)
C      SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (68).
C      CONSIDERATION OF THREE (3) CASES, INVOLVING 900 VALUES.
C      SUBROUTINE UNST7 (PI,R,H,T0,CK,R1,GAM,OMG,M,N)
C      DIMENSION OMG(20,20,3),COMG(20,20,3),A(20,20,3),B(20,20,3),DELO(20
1,20,3),C(20,20,3),D(20,20,3),F(20,20,3),BETA(20,20,3),BETA12(20,20
2,3),F1(4),X(4)
101   FORMAT (20X,6UHTABLE OF UNSTABLE VALUES OF THE THRUST FREQUENCY FO
1R EQUATION (68), RAD PER SEC.,//,4X,2HJ,,4X,2HK,,8X,10HCOMEGA (1),
210X,10HCOMEGA (2),10X,10HCOMEGA (3),//)
102   FORMAT (2I5, 3E20.8//)
103   FORMAT (20X,33HFIRST CASE, LOWER CASE M EQUAL 1.,//)
104   FORMAT (20X,34HSECOND CASE, LOWER CASE M EQUAL 2.,//)
105   FORMAT (20X,35HTHIRD CASE, LOWER CASE M EQUAL 3.,//)
DO 1 J=1,M
DO 1 K=1,N
DO 1 I=1,3
COMG(J,K,I)=0.0
1 CONTINUE
DO 2 J=2,M
DO 2 K=2,N
DO 2 I=1,3
START=1.
START1=1.
35   X(1)=START*(UMG(J,K,I))
DO 3 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)30,31,30
30   C2=2.***28
IF (B(J,K,I)-C2)300,301,301
31   DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 32
300  DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,I)))
32   C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)33,33,34
34   START=START-.1
IF (START)325,325,35
325  COMG(J,K,I)=.33333333
GO TO 2001
33   F(J,K,I)=PI-ASIN(D(J,K,I))
DETA(J,K,I)=(2./PI)*(F(J,K,I))
DETA12(J,K,I)=.5*(BETA(J,K,I))
F1(L)=OMG(J,K,I)/(ABS(-1.*DETA12(J,K,I)))
X(L+1)=F1(L)
4   X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)36,37,36
36   C2=2.***28
IF (B(J,K,I)-C2)300,401,401
37   DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,I)))
38   C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))

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38 IF (ABS(D(J,K+1))-1.)39,39,6
F(J,K,I)=PI-ABIG(J,J,K,I))
BETA(J,K+1)=(2.*PI)*(F(J,K,I))
BETA12(J,K+1)=.5*(BETA(J,K+1))
F1(3)=COMG(J,K,I)/(ABS(-1.*BETA12(J,K+1)))
D1=X(J)-F1(J)
IF (ABS(X(3))-1000.)390,394,394
390 IF (ABS(X(3))-100.)392,393,393
392 C1=.001
GO TO 395
393 C1=.01
GO TO 395
394 C1=.1
395 IF (ABS(L1)-C1)5,5,6
5 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF (START1-1000.)4,4,201
201 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF (A(J,K,I)-1.0)330,501,501
330 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K+1)-X(3))-C3)331,331,332
331 COMG(J,K,I)=.688888888
GO TO 2001
332 COMG(J,K,I)=.11111111
GO TO 2001
301 COMG(J,K,I)=.77777777
GO TO 2001
401 COMG(J,K,I)=.999999999
GO TO 2001
5 COMG(J,K,I)=ABS(X(3))
IF (A(J,K,I)-1.)2001,501,501
501 COMG(J,K,I)=.56606666
2001 CONTINUE
2 CONTINUE
WHITE(6,101)
WHITE(6,103)
GO 7 J=2,M
GO 7 K=2,N
J1=J-1
K1=K-1
WHITE(6,102) J1,K1,(COMG(J,K,I),I=1,3)
7 CONTINUE
GO 8 J=2,M
GO 8 K=2,N
GO 8 I=1,3
START1=1
START1=1.
45 X(1)=START*(COMG(J,K,I))
GO 9 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
L(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)40,41,40
40 L2=2.***28
IF (S(J,K,I)-C2)400,302,302
41 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 42

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400  DEL0(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1)))))/TAN(B(J,K,I))
42 C(J,K,I)=SQRT(ABS(DEL0(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)43,43,44
44 START=START+.1
IF (START-1.)45,45,425
425 COMG(J,K,I)=.33333333
GO TO 2002
43 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(L)=OMG(J,K,I)/(ABS(-1.+BETA12(J,K,I)))
9 X(L+1)=F1(L)
10 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(2.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
D(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)46,47,46
46 C2=2.***28
IF (D(J,K,I)-C2)460,402,402
47 DEL0(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 48
480  DEL0(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1)))))/TAN(B(J,K,I))
48 C(J,K,I)=SQRT(ABS(DEL0(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)49,49,42
49 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(3)=OMG(J,K,I)/(ABS(-1.+BETA12(J,K,I)))
L1=X(3)-F1(3)
IF (ABS(X(3))-1000.)490,494,494
490 IF (ABS(X(3))-100.)492,493,493
492 C1=.001
GO TO 495
493 C1=.01
GO TO 495
494 C1=.1
495 IF (ABS(D1)-C1)11,11,12
12 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF (START1-100.)10,10,202
202 A(J,K,I)=(2.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF (A(J,K,I)-1.)430,502,502
430 D(J,K,I)=(2.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(3))-C)431,431,432
431 COMG(J,K,I)=.38888888
GO TO 2002
432 COMG(J,K,I)=.11111111
GO TO 2002
302 COMG(J,K,I)=.77777777
GO TO 2002
402 COMG(J,K,I)=.99999999
GO TO 2002
11 COMG(J,K,I)=ABS(X(3))

```

```

      IF (A(J,K,I)-1.)2002,502,502
502  COMG(J,K,I)=.86666666
CONTINUE
0  CONTINUE
      WRITE (6,101)
      WRITE(6,104)
      DO 13 J=2,M
      DO 13 K=2,N
      J1=J-1
      K1=K-1
      WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)
13  CONTINUE
      DO 14 J=2,M
      DO 14 K=2,N
      DO 14 I=1,3
      STARTI=1.
      STARTI1=1.
55  X(I)=START*(OMG(J,K,I))
      DO 15 L=1,2
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF (A(J,K,I)-1.)50,51,50
50  C2=2.*28
      IF (B(J,K,I)-C2)500,303,303
51  DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.)
      GO TO 52
500  DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1.))))/TAN(B(J,K,I)))
52  C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF (ABS(D(J,K,I))-1.)53,53,54
53  START=START-.1
      IF (START)525,525,55
525  OMG(J,K,I)=.33333333
      GO TO 2003
53  F(J,K,I)=PI-ASIN(D(J,K,I))
      DELTA(J,K,I)=(2./PI)*(F(J,K,I))
      BETAI2(J,K,I)=.5*(BETA(J,K,I))
      F1(L)=(OMG(J,K,I))/(ABS(BETAI2(J,K,I)))
      X(L+1)=F1(L)
10  X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF (A(J,K,I)-1.)56,57,56
56  C2=2.*28
      IF (B(J,K,I)-C2)560,403,403
57  DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.)
      GO TO 58
500  DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1.))))/TAN(B(J,K,I)))
58  C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF (ABS(D(J,K,I))-1.)59,59,18
59  F(J,K,I)=PI-ASIN(D(J,K,I))
      DELTA(J,K,I)=(2./PI)*(F(J,K,I))
      BETAI2(J,K,I)=.5*(BETA(J,K,I))
      F1(3)=(OMG(J,K,I))/(ABS(BETAI2(J,K,I)))
      D1=X(3)-F1(3)
      IF (ABS(X(3))-1000.)590,494,594
590  IF (ABS(X(3))-100.)592,593,593
592  C1=.001

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593  GO TO 595
      C1=.01
      GO TO 595
594  C1=.1
595  IF (ABS(D1)-C1)17,17,18
18   X(1)=X(2)
     F1(1)=F1(2)
     X(2)=X(3)
     F1(2)=F1(3)
     START1=START1+1.
     IF (START1-1000.)16,16,203
203  A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
     IF (A(J,K,I)-1.0)530,503,503
530  B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
     C(J,K,I)=SQRT(B(J,K,I))
     C3=.01
     IF (ABS(C(J,K,I)-X(3))-C3)531,531,532
531  COMG(J,K,I)=.88888888
     GO TO 2003
532  COMG(J,K,I)=.11111111
     GO TO 2003
533  COMG(J,K,I)=.77777777
     GO TO 2003
403  COMG(J,K,I)=.99999999
     GO TO 2003
17   COMG(J,K,I)=ABS(X(3))
     IF (A(J,K,I)-1.)2003,503,503
503  COMG(J,K,I)=.66666666
2003  CONTINUE
14   CONTINUE
     WRITE(6,101)
     WRITE(6,105)
     DO 19 J=2,M
     DO 19 K=2,N
       J1=J-1
       K1=K-1
       WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,3)
19   CONTINUE
     RETURN.
END

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• I11 FOR UNSTB
C NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)
C SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (89).
C CONSIDERATION OF THREE (3) CASES, INVOLVING 900 VALUES.
C SUBROUTINE UNSTB (PI,R,H,TO,CK,RI,GAM,OMG,M,N)
C DIMENSION OMG(20,20,3),COMG(20,20,3),A(20,20,3),B(20,20,3),DFLU(20
1,20,3),C(20,20,3),D(20,20,3),F(20,20,3),BETA(20,20,3),BETA12(20,20
2,3),F1(4),X(4)
101 FORMAT (20X,8UHTABLE OF UNSTABLE VALUES OF THE THRUST FREQUENCY FU
1R EQUATION (89), RAD PER SEC.,//,4X,2HJ,,4X,2HK,,8X,10HC0MEGA (1),
21UX,10HC0MEGA (2),10X,10HC0MEGA (3),//)
102 FORMAT (215, 3E20.8//)
103 FORMAT (20X,33HFIRST CASE, LOWER CASE M EQUAL 1.,//)
104 FORMAT (20X,34HSECOND CASE, LOWER CASE M EQUAL 2.,//)
105 FORMAT (20X,33HTHIRD CASE, LOWER CASE M EQUAL 3.,//)
C 1 J=1,M
C 1 K=1,N
C 1 L=1,3
COMG(J,K,I)=0.0
CONTINUE
C 2 J=2,M
C 2 K=2,N
C 2 L=1,3
START=.1
START1=.1
35 A(1)=START*(OMG(J,K,I))
C 3 L=1,2
A(J,K,I)=(8.*PI*R*H*TO*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)30,31,30
30 C2=2.**28
IF (A(J,K,I)-C2)300,301,301
31 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 32
300 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
32 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ADJ(D(J,K,I))-1.)33,33,34
34 START=START+.1
IF (START-1.)35,35,325
325 COMG(J,K,I)=.33333333
GO TO 2001
33 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(L)=(OMG(J,K,I))/(ABS(2.-BETA12(J,K,I)))
3 A(L+1)=F1(L)
4 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*TO*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)36,37,36
36 C2=2.**28
IF (A(J,K,I)-C2)300,401,401
37 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 38
300 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
38 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))

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39 IF (ABS(D(J,K,I))-1.)39,39,6
   F(J,K,I)=ASIN(D(J,K,I))
   LT=TA(J,K,I)=(Z./PI)*(F(J,K,I))
   LT12(J,K,I)=.5*(BETA(J,K,I))
   F1(3)=(OMG(J,K,I))/(ABS(2.-BETA12(J,K,I)))
   U1=X(3)-F1(3)
   IF (ABS(X(3))-1000.)390,394,394
390 IF (ABS(X(3))-100.)392,393,393
392 C1=.001
   GO TO 395
393 C1=.01
   GO TO 395
394 C1=.1
395 IF (AUS(D1)-C1)5,5,6
6 X(1)=X(2)
   F1(1)=F1(2)
   X(2)=X(3)
   F1(2)=F1(3)
   START1=START1+1.
   IF (START1-100.)4,4,201
201 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
   IF (A(J,K,I)-1.0)330,501,501
330 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
   C(J,K,I)=SQRT(B(J,K,I))
   C3=.01
   IF (AUS(C(J,K,I))-X(3))-C3)331,331,332
331 COMG(J,K,I)=.88888888
   GO TO 2001
332 COMG(J,K,I)=.11111111
   GO TO 2001
301 COMG(J,K,I)=.77777777
   GO TO 2001
401 COMG(J,K,I)=.99999999
   GO TO 2001
5 COMG(J,K,I)=AUS(X(3))
   IF (A(J,K,I)-1.)2001,501,501
501 COMG(J,K,I)=.66666666
2001 CONTINUE
2 CONTINUE
   WH1TE(6,101)
   WH1TE(6,105)
   DO 7 J=2,M
   DO 7 I=2,N
   J1=J-1
   K1=K-1
   WH1TE(6,102) J1,K1,(COMG(J,K,I),I=1,3)
7 CONTINUE
   DO 8 J=2,M
   DO 8 I=2,N
   DO 8 L=1,3
   START1=1
   START1=1.
45 X(1)=START*(OMG(J,K,I))
   DO 9 L=1,2
   A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
   D(J,K,I)=.5*PI*SQRT(A(J,K,I))
   IF (A(J,K,I)-1.)40,41,40
40 C2=2.*28
   IF (L(J,K,I)-C2)400,302,302
41 UELU(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
   GO TO 42

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400 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I)
1))))/TAN(B(J,K,I))
42 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)43,43,44
44 START=START+.1
IF (START-1.0)45,45,425
45 COMG(J,K,I)=.33333333
50 TO 2002
43 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(L)=(OMG(J,K,I))/(ABS(1.+BETA12(J,K,I)))
55 X(L+1)=F1(L)
60 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)46,47,46
65 C=2.*#28
IF (B(J,K,I)-C)460,402,402
67 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
70 GO TO 48
480 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
490 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)49,49,49
495 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
BETA12(J,K,I)=.5*(BETA(J,K,I))
F1(3)=(OMG(J,K,I))/(ABS(1.+BETA12(J,K,I)))
500 U1=X(J)-F1(3)
IF (ABS(X(3))-1000.)490,494,494
490 IF (ABS(X(3))-100.)492,493,493
492 C1=.001
500 TO 495
493 C1=.01
500 TO 495
494 C1=.1
495 IF (ABS(D1)-C1)11,11,12
500 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
500 IF (START1-100.)10,10,202
502 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
504 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
506 C3=.01
508 IF (ABS(C(J,K,I)-X(3))-C3)431,431,432
510 COMG(J,K,I)=.88888888
512 GO TO 2002
432 COMG(J,K,I)=.11111111
514 GO TO 2002
502 COMG(J,K,I)=.77777777
516 GO TO 2002
402 COMG(J,K,I)=.99999999
518 GO TO 2002
11 COMG(J,K,I)=ABS(X(3))

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502 IF (A(J,K,I)-1.)2002,502,502
      COMG(J,K,I)=.66666666
2002 CONTINUE
      CONTINUE
      WRITE(6,101)
      WRITE(6,104)
      DO 13 J=2,M
      DO 13 K=2,N
      J1=J-1
      K1=K-1
      WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)
13  CONTINUE
      DO 14 J=2,M
      DO 14 K=2,N
      DO 14 I=1,3
      STARTZ=1.
      STARTI=1.
      STARTIZ=1.0
55   X(1)=START*(OMG(J,K,I))
      DO 15 L=1,2
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF (A(J,K,I)-1.)50,51,50
50   C2=2.**28
      IF (C(J,K,I)-C2)500,303,303
51   DEL0(J,K,I)=1.+ (PI*PI*GAM*GAM)/64.
      GO TO 52
500  DEL0(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
     1)))))/TAN(B(J,K,I))
52   C(J,K,I)=SQRT(ABS(DEL0(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF (ABS(D(J,K,I))-1.)53,53,54.
54   START=START+.1
      IF (START-1.0)55,55,525
525  COMG(J,K,I)=.33333333
      GO TO 2003
55   F(J,K,I)=ASIN(D(J,K,I))
      BETAT(J,K,I)=(2./PI)*(F(J,K,I))
      BETAT12(J,K,I)=.5*(BETAT(J,K,I))
      F1(L)=OMG(J,K,I)/(ABS(2.+BETAT12(J,K,I)))
15   X(L+1)=F1(L)
16   X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF (A(J,K,I)-1.)56,57,56
56   C2=2.**28
      IF (C(J,K,I)-C2)560,403,403
57   DEL0(J,K,I)=1.+ (PI*PI*GAM*GAM)/64.
      GO TO 58
500  DEL0(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I
     1)))))/TAN(B(J,K,I))
58   C(J,K,I)=SQRT(ABS(DEL0(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF (ABS(D(J,K,I))-1.)59,59,58
59   F(J,K,I)=ASIN(D(J,K,I))
      BETAT(J,K,I)=(2./PI)*(F(J,K,I))
      BETAT12(J,K,I)=.5*(BETAT(J,K,I))
      F1(3)=OMG(J,K,I)/(ABS(2.+BETAT12(J,K,I)))
      J1=X(3)-F1(3)
      IF (ABS(X(3))-1000.)590,594,594
590  IF (ABS(X(3))-100.)592,593,593

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592 C1=.001
593 C1=.01
594 C1=.1
595 IF (ABS(C1)-C1)17,17,18
16 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
1F (START1-100.)16,16,203
203 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF (A(J,K,I)-1.0)530,503,503
530 C(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I))-X(3))-C3)531,531,532
531 COMG(J,K,I)=.38888888
532 COMG(J,K,I)=.11111111
533 COMG(J,K,I)=.77777777
534 COMG(J,K,I)=.99999999
535 COMG(J,K,I)=.66666666
2003 CONTINUE
14 CONTINUE
      WRITE (6,101)
      WRITE (6,105)
      DO 19 J=2,M
      DO 19 K=2,N
      J1=J-1
      K1=K-1
      WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)
19 CONTINUE
      RETURN
END

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      FOR UNST9
C   NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)
C   SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (90).
C   CONSIDERATION OF 9 CASES(3 INADMISSIBLE), INVOLVING 1800 VALUES.
C   SUBROUTINE UNST9 (P1,R,H,T0,LK,RI,GAM,OMG,M,N)
C   DIMENSION OMG(20,20,3),COMG(20,20,3),A(20,20,3),B(20,20,3),DELU(20
101  1,20,3),C(20,20,3),D(20,20,3),F(20,20,3),BETA(20,20,3),F1(4),X(4)
      FORMAT (20X,80HTABLE OF UNSTABLE VALUES OF THE THRUST FREQUENCY FU
1R EQUATION (90), RAD PER SEC.,//,4X,2HJ,,4X,2HK,,8X,10HCOMEGA (1),
210X,10HCOMEGA (2),10X,10HCOMEGA (3),//)
102  FORMAT (2I5, 3E20.8//)
103  FORMAT (10X,78HFIRST CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUA
1L 1, (CASE NOT ADMISSIBLE).///)
104  FORMAT (10X,56HSECOND CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUA
1AL 1,//)
105  FORMAT (10X,55HTHIRD CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUA
1L 1,//)
106  FORMAT (10X,56HFOURTH CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUA
1AL 2,//)
107  FORMAT (10X,78HFIFTH CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUA
1L 2, (CASE NOT ADMISSIBLE).///)
108  FORMAT (10X,55HSIXTH CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUA
1L 2,//)
109  FORMAT (10X,57HSEVENTH CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUA
1AL 3,//)
110  FORMAT (10X,56HEIGHTH CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUA
1AL 3,//)
111  FORMAT (10X,78HNINTH CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUA
1L 3, (CASE NOT ADMISSIBLE).//)

      DO 1 J=1,M
      DO 1 K=1,N
      DO 1 I=1,3
      COMG(J,K,I)=0.0
1     CONTINUE
      WRITE (6,101)
      WRITE (6,103)
      DO 2 J=2,M
      DO 2 K=2,N
      DO 2 I=1,3
      START_1
      START1=1.
35      X(1)=START*(OMG(J,K,I))
      DO 3 L=1,2
      A(J,K,I)=(8.*PI*R*H*T0*C(K))/(R*I*X(L)*X(L))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF (A(J,K,I)-1.)30,31,30
30      C2=2.**28
      IF (.-(J,K,I)-L2)300,301,301
31      DEL0(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
      GO TO 32
300     DEL0(J,K,I)=1.+((PI*(-(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,I)))
32      C(J,K,I)=SQRT(ABS(DEL0(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF (ABS(D(J,K,I))-1.)33,33,34
33      START=START+.1
      IF (START-1.0)35,35,325
325     COMG(J,K,I)=.33333333
      GO TO 2001
33      F(J,K,I)=ASIN(D(J,K,I))

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300 ELETA(J,K,I)=(2./PI)*(F(J,K,1))
      F1(L)=(OMG(J,K,I))/(ABS(-1.+BETA(J,K,I)))
      X(L+1)=F1(L)
      4
      X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF(A(J,K,I)-1.)30,37,36
      30 C2=2.***28
      IF(B(J,K,I)-C2)360,401,401
      37 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 38
      380 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
      1))))/TAN(B(J,K,I)))
      38 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF(Abs(D(J,K,I))-1.)39,39,6
      39 F(J,K,I)=ASIN(D(J,K,I))
      BETA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(3)=(OMG(J,K,I))/(ABS(-1.+BETA(J,K,I)))
      D1=X(3)-F1(3)
      IF(Abs(X(3))-1000.)390,394,394
      390 IF(Abs(X(3))-100.)392,393,393
      392 C1=.001
      GO TO 395
      393 C1=.01
      GO TO 395
      394 C1=.1
      395 IF(Abs(D1)-C1)5,5,6
      6 X(1)=X(2)
      F1(1)=F1(2)
      X(2)=X(3)
      F1(2)=F1(3)
      START1=START1+1.
      IF(START1-100.)4,4,201
      201 A(J,K,1)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
      IF(A(J,K,I)-1.0)330,501,501
      330 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
      C(J,K,I)=SQRT(B(J,K,I))
      C3=.01
      IF(Abs(C(J,K,I)-X(3))-C3)331,331,332
      331 COMG(J,K,I)=.88888888
      GO TO 2001
      332 COMG(J,K,I)=.11111111
      GO TO 2001
      301 COMG(J,K,I)=.77777777
      GO TO 2001
      401 COMG(J,K,I)=.99999999
      GO TO 2001
      5 COMG(J,K,I)=Abs(X(3))
      IF(A(J,K,I)-1.)2001,501,501
      501 COMG(J,K,I)=.06666666
      2001 CONTINUE
      2 CONTINUE
      WRITE(6,101)
      WRITE(6,104)
      DO 7 J=2,M
      DO 7 K=2,N
      J1=J-1
      K1=K-1
      7 WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,3)
      CONTINUE

```

```

      DO 8 J=2,N
      DO 8 K=2,N
      DO 8 I=1,3
      START=6
      START1=1.
      45 X(1)=START*(OMG(J,K,I))
      DO 9 L=1,2
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF(A(J,K,I)-1.)40,41,40
      40 C2=2.***28
      IF(B(J,K,I)-C2)400,302,302
      41 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
      GO TO 42
      400 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I)
      1))))/TAN(B(J,K,I))
      42 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF(ABS(D(J,K,I))-1.)43,43,44
      44 START=START-.1
      IF(START)425,425,45
      425 OMG(J,K,I)=.33333333
      GO TO 2002
      45 F(J,K,I)=PI-ASIN(D(J,K,I))
      BETA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(L)=(OMG(J,K,I))/(ABS(BETA(J,K,I)))
      9 X(L+1)=F1(L)
      10 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF(A(J,K,I)-1.)46,47,46
      46 C2=2.***28
      IF(B(J,K,I)-C2)460,402,402
      47 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 48
      400 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I)
      1))))/TAN(B(J,K,I))
      48 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF(ABS(D(J,K,I))-1.)49,49,12
      49 F(J,K,I)=PI-ASIN(D(J,K,I))
      BETA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(3)=(OMG(J,K,I))/(ABS(BETA(J,K,I)))
      D1=X(3)-F1(3)
      IF(ABS(X(3))-1000.)490,494,494
      490 IF(ABS(X(3))-100.)492,493,493
      492 C1=.001
      GO TO 495
      493 C1=.01
      GO TO 495
      494 C1=.1
      495 IF(ABS(D1)-C1)11,11,12
      12 X(1)=X(2)
      F1(1)=F1(2)
      X(2)=X(3)
      F1(2)=F1(3)
      START1=START1+1.
      IF(START1-1000.)10,10,202
      202 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
      IF(A(J,K,I)-1.0)430,502,502
      430 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)

```

```

C(J,K,I)=SGRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(3))-C3)431,431,432
431 CUMG(J,K,I)=.688888888
GO TO 2002
432 CUMG(J,K,I)=.111111111
GO TO 2002
502 CUMG(J,K,I)=.777777777
GO TO 2002
402 CUMG(J,K,I)=.999999999
GO TO 2002
11 CUMG(J,K,I)=ABS(X(3))
IF (A(J,K,I)-1.)2002,502,502
502 CUMG(J,K,I)=.666666666
2002 CONTINUE
0 CONTINUE
WHITE(0,101)
WHITE(0,105)
DO 13 J=2,M
DO 13 K=2,N
Ji=J-1
K1=K-1
WHITE (0,102) J1,K1,(COMG(J,K,I),I=1,3)
13 CONTINUE
DO 14 J=2,M
DO 14 K=2,N
DO 14 I=1,3
START1=.1
START1=1.
55 X(1)=START*(OMG(J,K,I))
DO 15 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SGRT(A(J,K,I))
IF (A(J,K,I)-1.)50,51,50
50 C2=2.**28
IF (B(J,K,I)-C2)500,303,303
51 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 52
500 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I)
1))))/TAN(B(J,K,I)))
52 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)53,53,54
53 START=START+.1
IF (START-1.0)55,55,525
525 COMG(J,K,I)=.333333333
GO TO 2003
53 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(L)=OMG(J,K,I)/(ABS(1.-BETA(J,K,I)))
15 X(L+1)=F1(L)
16 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)56,57,56
56 C2=2.**28
IF (B(J,K,I)-C2)560,403,403
57 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 58
580 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I)
1))))/TAN(B(J,K,I)))

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```

56 C(J,K,I)=SQRT(ABS(DEL0(J,K,I)))
57 U(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
58 IF (ABS(U(J,K,I))-1.)59,59,18
59 F(J,K,I)=ASIN(D(J,K,I))
60 BLTA(J,K,I)=(2./PI)*(F(J,K,I))
61 F1(3)=(OMG(J,K,I))/(ABS(1.-BLTA(J,K,I)))
62 D1=X(3)-F1(3)
63 IF (ABS(X(3))-1000.)590,594,594
64 IF (ABS(X(3))-100.)592,593,593
65 C1=.001
66 GO TO 595
67 C1=.01
68 GO TO 595
69 C1=.1
70 IF (ABS(D1)-C1)17,17,18
71 X(1)=X(2)
72 F1(1)=F1(2)
73 X(2)=X(3)
74 F1(2)=F1(3)
75 START1=START1+1.
76 IF (START1-100.)16,16,203
77 R(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
78 IF (A(J,K,I)-1.0)530,503,503
79 O(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
80 U(J,K,I)=SQRT(B(J,K,I))
81 C3=.01
82 IF (ABS(C(J,K,I)-X(3))-C3)531,531,532
83 COMG(J,K,I)=.88888888
84 GO TO 2003
85 COMG(J,K,I)=.11111111
86 GO TO 2003
87 COMG(J,K,I)=.77777777
88 GO TO 2003
89 COMG(J,K,I)=.99999999
90 GO TO 2003
91 COMG(J,K,I)=ABS(X(3))
92 IF (A(J,K,I)-1.)2003,503,503
93 COMG(J,K,I)=.66666666
94 CONTINUE
95 CONTINUE
96 WRITE (6,101)
97 WRITE (6,106)
98 DO 19 J=2,M
99 DO 19 K=2,N
100 J1=J-1
101 K1=K-1
102 WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)
103 CONTINUE
104 WRITE (6,101)
105 WRITE (6,107)
106 DO 20 J=2,M
107 DO 20 K=2,N
108 DO 20 I=1,3
109 COMG(J,K,I)=OMG(J,K,I)
110 CONTINUE
111 WRITE (6,101)
112 WRITE (6,108)
113 DO 21 J=2,M
114 DO 21 K=2,N
115 J1=J-1
116 K1=K-1

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```

21      WRITE(6,102) J1,K1,(OMG(J,K,I),I=1,3)
      CONTINUE
      DO 22 J=2,N
      DO 22 K=2,N
      DO 22 I=1,3
      START=1.6
      START1=1.
      X(1)=START+(OMG(J,K,I))
      DO 23 L=1,2
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF(A(J,K,I)-1.)60,61,60
      C2=2.*28
      IF(B(J,K,I)-C2)600,304,304
      61  DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 62
      600 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
      1)))))/TAN(B(J,K,I)))
      62  C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF(ADE(D(J,K,I))-1.)63,63,64
      64  START=START-.1
      IF(START)625,625,65
      625 OMG(J,K,I)=.33333333
      GO TO 2004
      63  F(J,K,I)=PI-ASIN(D(J,K,I))
      BETTA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(L)=(OMG(J,K,I))/(ABS(-1.*BETTA(J,K,I)))
      X(L+1)=F1(L)
      64  X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF(A(J,K,I)-1.)66,67,66
      C2=2.*28
      IF(B(J,K,I)-C2)660,404,404
      67  DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 68
      660 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
      1)))))/TAN(B(J,K,I)))
      68  C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF(ADE(D(J,K,I))-1.)69,69,26
      69  F(J,K,I)=PI-ASIN(D(J,K,I))
      BETTA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(3)=(OMG(J,K,I))/(ABS(-1.*BETTA(J,K,I)))
      C1=X(3)-F1(3)
      IF(ADE(X(3))-1000.)690,694,694
      IF(ADE(X(3))-100.)692,693,693
      692 C1=.001
      GO TO 695
      693 C1=.01
      GO TO 695
      694 C1=.1
      695 IF(ADE(D1)-C1)25,25,26
      X(1)=X(2)
      F1(1)=F1(2)
      X(2)=X(3)
      F1(2)=F1(3)
      START1=START1+1.
      IF(START1-1000.)24,24,204
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))

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```

630 IF (K(J,K,I)-1.0)630,504,504
      C(J,K,I)=(E.*PI*R*H*T0*C(K))/(R(I))
      C3=SQRT(B(J,K,I))
      C3=.01
      1F (A0,J(C(J,K,I)-X(3))-C3)631,631,632
      COMG(J,K,I)=.88888888
      GO TO 2004
  632 COMG(J,K,I)=.11111111
      GO TO 2004
  304 COMG(J,K,I)=.77777777
      GO TO 2004
  404 COMG(J,K,I)=.99999999
      GO TO 2004
  65 COMG(J,K,I)=ADS(X(3))
      1F (A(J,K,I)-1.0)2004,504,504
  504 COMG(J,K,I)=.06666666
  2004 CONTINUE
  22 CONTINUE
      WRITE (6,101)
      WRITE (6,109)
      DO 27 J=2,M
      DO 27 K=2,N
      J1=J-1
      K1=K-1
      27 WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)
      CONTINUE
      DO 28 J=2,M
      DO 28 K=2,N
      DO 28 I=1,3
      COMG(J,K,I)=UMG(J,K,I)
      28 CONTINUE
      WRITE (6,101)
      WRITE (6,110)
      DO 29 J=2,M
      DO 29 K=2,N
      J1=J-1
      K1=K-1
      29 WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)
      CONTINUE
      WRITE (6,101)
      WRITE (6,111)
      RETURN,
      END

```

```

*1 FOR UNST10
C NASA CONTRACT NAS8-11245 (LONGITUDINAL VIBRATION RESEARCH)
C SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (91).
C CONSIDERATION OF 9 CASES (3 INADMISSIBLE), INVOLVING 1800 VALUES.
C SUBROUTINE UNST10(PI,R,H,TO,CK,RI,GAM,OMG,M,N)
C DIMENSION OMG(20,20,3),COMG(20,20,3),A(20,20,3),B(20,20,3),DEL0(20
101 1,20,3),C(20,20,3),D(20,20,3),F(20,20,3),BETA(20,20,3),F1(4),X(4)
FORMAT (20X,8HUNSTABLE OF UNSTABLE VALUES OF THE THRUST FREQUENCY FU
1R EQUATION (91), RAD PER SEC.,//,4X,2HJ,,4X,2HK,,8X,10HCOMEGA (1),
210X,10HCOMEGA (2),10X,10HCOMEGA (3),//)
102 FORMAT (2I5, 3E20.8//)
103 FORMAT (10X,7HFIRST CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUAL
1L 1, (CASE NOT ADMISSIBLE).///)
104 FORMAT (10X,5HSSECOND CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUAL
1AL 1,//)
105 FORMAT (10X,5SHTHIRD CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUAL
1L 1,//)
106 FORMAT (10X,5SHFOURTH CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUAL
1AL 2,//)
107 FORMAT (10X,7HFIFTH CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUAL
1L 2, (CASE NOT ADMISSIBLE).///)
108 FORMAT (10X,5HSIXTH CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUAL
1L 2,//)
109 FORMAT (10X,57HSEVENTH CASE, LOWER CASE M EQUAL 1, LOWER CASE N EQUAL
1AL 3,//)
110 FORMAT (10X,56HEIGHTH CASE, LOWER CASE M EQUAL 2, LOWER CASE N EQUAL
1AL 3,//)
111 FORMAT (10X,78HNINTH CASE, LOWER CASE M EQUAL 3, LOWER CASE N EQUAL
1L 3, (CASE NOT ADMISSIBLE).//)

      DO 1 J=1,M
      DO 1 K=1,N
      DO 1 I=1,3
      COMG(J,K,I)=0.0
1 CONTINUE
      WRITE (6,101)
      WRITE (6,103)
      DO 2 J=2,M
      DO 2 K=2,N
      DO 2 I=1,3
      COMG(J,K,I)=OMG(J,K,I)
2 CONTINUE
      WRITE (6,101)
      WRITE (6,104)
      DO 3 J=2,M
      DO 3 K=2,N
      J1=J-1
      K1=K-1
      WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)
3 CONTINUE
      DO 4 J=2,M
      DO 4 K=2,N
      DO 4 I=1,3
      COMG(J,K,I)=.5*(OMG(J,K,I))
4 CONTINUE
      WRITE (6,101)
      WRITE (6,105)
      DO 5 J=2,M
      DO 5 K=2,N
      J1=J-1
      K1=K-1

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```

5      WRITE (6,102) J1,K1,(OMG(J,K,I),I=1,3)
CONTINUE
DO 6 J=2,M
DO 6 K=2,N
DO 6 I=1,3
OMG(J,K,I)=0.0
6      CONTINUE
WRITE (6,101)
WRITE (6,105)
DO 7 J=2,M
DO 7 K=2,N
J1=J-1
K1=K-1
WRITE (6,102) J1,K1,(OMG(J,K,I),I=1,3)
7      CONTINUE
WRITE (6,101)
WRITE (6,107)
DO 8 J=2,M
DO 8 K=2,N
DO 8 I=1,3
START=L+1
START1=1.
8      X(1)=START*(OMG(J,K,I))
DO 9 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF(A(J,K,I)-1.)30,31,30
30     C2=2.***28
IF(L(J,K,I)-C2)300,301,301
31     DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
DO 32 32
32     DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I))))/TAN(B(J,K,I)))
C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF(ABS(D(J,K,I))-1.)33,33,34
34     START=START+.1
IF(START-1.)35,35,325
35     OMG(J,K,I)=.33333333
DO 36 36
36     F(J,K,I)=ASIN(D(J,K,I))
DETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(L)=(OMG(J,K,I))/(ABS(1.+BETA(J,K,I)))
9      X(L+1)=F1(L)
10     X(3)=(X(1)+F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF(A(J,K,I)-1.)30,37,36
36     C2=2.***28
IF(L(J,K,I)-L2)300,401,401
37     DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
DO 38 38
38     DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*(1.-(A(J,K,I))))/TAN(B(J,K,I)))
C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF(ABS(D(J,K,I))-1.)39,39,12
49     F(J,K,I)=ASIN(D(J,K,I))
DETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(3)=(OMG(J,K,I))/(ABS(1.+BETA(J,K,I)))
D1=X(J)-F1(J)

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```

      IF (ABS(X(3))-1000.)390,394,394
 390  IF (ABS(X(3))-100.)392,393,393
 392  C1=.001
      GO TO 395
 393  C1=.01
      GO TO 395
 394  C1=.1
 395  IF (ABS(D1)-C1)11,11,12
 12   X(1)=X(2)
      F1(1)=F1(2)
      X(2)=X(3)
      F1(2)=F1(3)
      START1=START1+1.
 11   IF (START1-100.)10,10,201
 201  A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
      IF (A(J,K,I)-1.0)330,501,501
 330  B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
      C(J,K,I)=SQRT(B(J,K,I))
      C3=.01
      IF (ABS(C(J,K,I))-X(3))-C3)331,331,332
 331  COMG(J,K,I)=.88888888
      GO TO 2001
 332  COMG(J,K,I)=.11111111
      GO TO 2001
 301  COMG(J,K,I)=.77777777
      GO TO 2001
 401  COMG(J,K,I)=.99999999
      GO TO 2001
 11   COMG(J,K,I)=ABS(X(3))
      IF (A(J,K,I)-1.)2001,501,501
 501  COMG(J,K,I)=.66666666
 2001  CONTINUE
 8    CONTINUE
      WRITE (6,101)
      WRITE (6,108)
      DO 13 J=2,M
      DO 13 K=2,N
      J1=J-1
      K1=K-1
      WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)
 13   CONTINUE
      DO 14 J=2,M
      DO 14 K=2,N
      DO 14 I=1,3
      COMG(J,K,I)=.5*(OMG(J,K,I))
 14   CONTINUE
      WRITE (6,101)
      WRITE (6,109)
      DO 15 J=2,M
      DO 15 K=2,N
      J1=J-1
      K1=K-1
      WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)
 15   CONTINUE
      DO 16 J=2,M
      DO 16 K=2,N
      DO 16 I=1,3
      STARTE=1
      START1=1.
 45   X(1)=START*(OMG(J,K,I))
      DO 17 L=1,2

```

```

A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF(A(J,K,I)-1.)40,41,40
40 C2=2.***28
IF(B(J,K,I)-C2)400,302,302
DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 42
400 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
42 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF(ABD(D(J,K,I))-1.)43,43,44
44 START=START+.1
IF(START-1.)45,45,425
425 OMG(J,K,I)=.33333333
GO TO 2002
45 F(J,K,I)=ASIN(D(J,K,I))
BTa(J,K,I)=(2./PI)*(F(J,K,I))
F1(L)=(OMG(J,K,I))/(ABS(1.+BLTA(J,K,I)))
X(L+1)=F1(L)
46 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF(A(J,K,I)-1.)46,47,46
46 C2=2.***28
IF(B(J,K,I)-C2)460,402,402
47 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GO TO 48
480 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
48 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF(ABD(D(J,K,I))-1.)49,49,20
49 F(J,K,I)=ASIN(D(J,K,I))
BTa(J,K,I)=(2./PI)*(F(J,K,I))
F1(3)=(OMG(J,K,I))/(ABS(1.+BLTA(J,K,I)))
D1=X(3)-F1(3)
IF(ABD(X(3))-1000.)490,494,494
490 IF(ABD(X(3))-100.)492,493,493
492 C1=.001
GO TO 495
493 C1=.01
GO TO 495
494 C1=.1
495 IF(ABD(D1)-C1)19,19,20
20 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF(START1-100.)18,18,202
202 X(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF(A(J,K,I)-1.0)430,502,502
430 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF(ABD(C(J,K,I)-X(3))-C3)431,431,432
C OMG(J,K,I)=.08888888
GO TO 2002
432 OMG(J,K,I)=.11111111
GO TO 2002

```

362 COMG(J,K,I)=.77777777  
60 TO 2002  
462 COMG(J,K,I)=.99999999  
60 TO 2002  
19 COMG(J,K,I)=ABS(X(3))  
IF (A(J,K,I)-1.)2002,502,502  
502 COMG(J,K,I)=.66666666  
2002 CONTINUE  
16 CONTINUE  
WRITE (6,101)  
WRITE (6,110)  
DO 21 J=2,M  
DO 21 K=2,N  
J1=J-1  
K1=K-1  
WRITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)  
21 CONTINUE  
WRITE (6,101)  
WRITE (6,111)  
RETURN.  
END

```

101 FOR UNST11
C NASA CONTRACT NAS8-11255 (LONGITUDINAL VIBRATION RESEARCH)
C SUBROUTINE FOR UNSTABLE VALUES OF THRUST FREQUENCY, EQUATION (92).
C CONSIDERATION OF THREE (3) CASES, INVOLVING 900 VALUES.
SUBROUTINE UNST11(PI,R,H,TO,CK,RI,GAM,OMG,M,N)
DIMENSION OMG(20,20,3),COMG(20,20,3),A(20,20,3),B(20,20,3),DELO(20
1,20,3),C(20,20,3),D(20,20,3),F(20,20,3),BETA(20,20,3),F1(4),X(4)
101 FORMAT (20X,8UHTABLE OF UNSTABLE VALUES OF THE THRUST FREQUENCY FO
1R EQUATION (92), RAD PER SEC.,//,4X,2HJ,,4X,2HK,,8X,10HCOMEGA (1),
21UX,10HCOMEGA (2),10X,10HCOMEGA (3),//)
102 FORMAT (2I5, 3E20.8//)
103 FORMAT (20X,33HFIRST CASE, LOWER CASE M EQUAL 1.,//)
104 FORMAT (20X,34HSECOND CASE, LOWER CASE M EQUAL 2.,//)
105 FORMAT (20X,33HTHIRD CASE, LOWER CASE M EQUAL 3.,//)
DO 1 J=1,M
DO 1 K=1,N
DO 1 I=1,3
COMG(J,K,I)=0.0
1 CONTINUE
DO 2 J=2,M
DO 2 K=2,N
DO 2 I=1,3
STARTZ=.1
START1=.1
35 X(1)=START*(OMG(J,K,I))
DO 3 L=1,2
A(J,K,I)=(8.*PI*R*H*TO*CK)/(KI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)30,31,30
30 C2=2.**28
IF (B(J,K,I)-C2)300,301,301
31 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 32
300 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
32 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)33,33,34
34 STARTZ=START+.1
IF (START-1.0)35,35,325
325 COMG(J,K,I)=.33333333
GO TO 2001
53 F(J,K,I)=ASIN(D(J,K,I))
IF (A(J,K,I)=(2./PI)*(F(J,K,I)))
F(L)=OMG(J,K,I)/(ABS(2.-BETA(J,K,I)))
3 x(L+1)=F1(L)
4 x(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
n(J,K,I)=(8.*PI*R*H*TO*CK)/(KI*X(3)*X(3))
D(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (n(J,K,I)-1.)36,37,36
36 C2=2.**28
IF (n(J,K,I)-C2)360,401,401
37 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 38
300 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1))))/TAN(B(J,K,I)))
38 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)39,39,39
39 F(J,K,I)=ASIN(D(J,K,I))

```

```

BETA(J,K,I)=(Z0/PI)*(F(J,K,I))
F1(3)=OMG(J,K,I)/(ABS(Z0-BETA(J,K,I)))
C1=X(3)-F1(3)
IF(ABS(X(3))-1000.)390,394,394
IF(ABS(X(3))-100.)392,393,395
C1=.001
GO TO 395
393 C1=.01
GO TO 395
394 C1=.1
395 IF(ABS(D1)-C1)5,5,6
6 X(1)=X(2)
F1(1)=F1(2)
X(2)=X(3)
F1(2)=F1(3)
START1=START1+1.
IF(START1-1000.)4,4,201
201 A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF(A(J,K,I)-1.0)330,501,501
330 B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SQRT(B(J,K,I))
C3=.01
IF(ABS(C(J,K,I)-X(3))-C3)331,331,332
331 COMG(J,K,I)=.88888888
GO TO 2001
332 COMG(J,K,I)=.11111111
GO TO 2001
301 COMG(J,K,I)=.77777777
GO TO 2001
401 COMG(J,K,I)=.99999999
GO TO 2001
5 COMG(J,K,I)=ABS(X(3))
IF(A(J,K,I)-1.)2001,501,501
501 COMG(J,K,I)=.66666666
2001 CONTINUE
2 CONTINUE
WRITE(6,101)
WRITE(6,103)
DO 7 J=2,M
DO 7 K=2,N
J1=J-1
K1=K-1
WRITE(6,102) J1,K1,(COMG(J,K,I),I=1,3)
7 CONTINUE
DO 8 J=2,M
DO 8 K=2,N
DO 8 I=1,3
START=.6
START1=1.
45 X(1)=START*(OMG(J,K,I))
DO 9 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF(A(J,K,I)-1.)40,41,40
40 C2=2.*28
IF(B(J,K,I)-C2)400,302,302
302 DELO(J,K,I)=1.+(PI*PI*GAM*GAM)/64.
GO TO 42
400 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I)
1)))))/TAN(B(J,K,I))
42 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))

```

```

      U(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF (ABS(D(J,K,I))-1.)43,43,44
44    START=START-.1
      IF (START)425,425,45
425   COMG(J,K,I)=.53333333
      GO TO 2002
      F(J,K,I)=PI-ASIN(D(J,K,I))
      BETA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(L)=(OMG(J,K,I))/(ABS(BETA(J,K,I)))
9     X(L+1)=F1(L)
10    X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
      A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
      B(J,K,I)=.5*PI*SQRT(A(J,K,I))
      IF (A(J,K,I)-1.)46,47,46
46    C2=2.*28
      IF (E(J,K,I)-C2)460,402,402
47    DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
      GO TO 48
480   DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I)
1 )))/TAN(B(J,K,I)))
48   C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
      D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
      IF (ABS(D(J,K,I))-1.)49,49,12
49    F(J,K,I)=PI-ASIN(D(J,K,I))
      BETA(J,K,I)=(2./PI)*(F(J,K,I))
      F1(3)=(OMG(J,K,I))/(ABS(BETA(J,K,I)))
      D1=X(3)-F1(3)
      IF (ABS(X(3))-1000.)490,494,494
490   IF (ABS(X(3))-100.)492,493,493
492   C1=.001
      GO TO 495
493   C1=.01
      GO TO 495
494   C1=.1
495   IF (ABS(D1)-C1)11,11,12
12    X(1)=X(2)
      F1(1)=F1(2)
      X(2)=X(3)
      F1(2)=F1(3)
      START1=START1+1.
      IF (START1-1000.)10,10,202
202   A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
      IF (A(J,K,I)-1.0)430,502,502
430   B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
      C(J,K,I)=SQRT(B(J,K,I))
      C3=.01
      IF (ABS(C(J,K,I)-X(3))-C3)431,431,432
431   COMG(J,K,I)=.88888888
      GO TO 2002
432   COMG(J,K,I)=.11111111
      GO TO 2002
502   COMG(J,K,I)=.77777777
      GO TO 2002
402   COMG(J,K,I)=.99999999
      GO TO 2002
11    COMG(J,K,I)=ABS(X(3))
      IF (A(J,K,I)-1.)2002,502,502
502   COMG(J,K,I)=.06666666
      CONTINUE
8     CONTINUE
      WRITE (6,101)

```

```

40 J= (6,104)
50 I3 J=2,M
50 I3 K=2,N
J1=J-1
K1=K-1
M=11L (6,102) J1,K1,(COMG(J,K,I),I=1,3)
CONTINUE
50 I4 J=2,M
50 I4 K=2,N
50 I4 I=1,3
START=.1
STARTI=1.
55 X(1)=START*(OMG(J,K,I))
50 I5 L=1,2
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(L)*X(L))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (I(J,K,I)-1.)50,51,50
50 C2=2.**28
IF (I(J,K,I)-C2)500,303,303
51 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GC TU 52
500 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,I)))
52 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)53,53,54
54 START=START+.1
IF (START-1.0)55,55,525
525 COMG(J,K,I)=.33333333
GO TU 2003
53 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(L)=(OMG(J,K,I))/(ABS(2.+BETA(J,K,I)))
55 X(L+1)=F1(L)
10 X(3)=(X(1)*F1(2)-X(2)*F1(1))/(X(1)-F1(1)-X(2)+F1(2))
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
B(J,K,I)=.5*PI*SQRT(A(J,K,I))
IF (A(J,K,I)-1.)56,57,56
56 C2=2.**28
IF (I(J,K,I)-C2)560,403,403
57 DELO(J,K,I)=1.+((PI*PI*GAM*GAM)/64.
GC TU 58
500 DELO(J,K,I)=1.+((PI*(A(J,K,I)**(3./2.))*GAM*GAM)/(16.*((1.-(A(J,K,I
1)))))/TAN(B(J,K,I)))
58 C(J,K,I)=SQRT(ABS(DELO(J,K,I)))
D(J,K,I)=(C(J,K,I))*(SIN(B(J,K,I)))
IF (ABS(D(J,K,I))-1.)59,59,18
59 F(J,K,I)=ASIN(D(J,K,I))
BETA(J,K,I)=(2./PI)*(F(J,K,I))
F1(3)=(OMG(J,K,I))/(ABS(2.+BETA(J,K,I)))
D1=X(3)-F1(3)
IF (ABS(X(3))-1000.)590,.594,594
590 IF (ABS(X(3))-100.)592,593,593
592 C1=.001
GO TU 595
593 C1=.01
GO TU 595
594 C1=.1
595 IF (ABS(D1)-C1)17,17,18
18 X(1)=X(2)
F1(1)=F1(2)

```

```

 $\wedge(2)=\wedge(3)$ 
F1(2)=F1(3)
START1=START1+1.
IF (START1=100.) 16,16,203
A(J,K,I)=(8.*PI*R*H*T0*CK)/(RI*X(3)*X(3))
IF ( $\wedge(J,K,I)=1.0$ ) 530,503,503
B(J,K,I)=(8.*PI*R*H*T0*CK)/(RI)
C(J,K,I)=SGRT(B(J,K,I))
C3=.01
IF (ABS(C(J,K,I)-X(3))-C3) 531,531,532
COMG(J,K,I)=.88888888
GO TO 2003
532 COMG(J,K,I)=.11111111
GO TO 2003
303 COMG(J,K,I)=.77777777
GO TO 2003
403 COMG(J,K,I)=.99999999
GO TO 2003
17 COMG(J,K,I)=ADS(X(3))
IF ( $\wedge(J,K,I)=1.0$ ) 2003,503,503
503 COMG(J,K,I)=.06666666
2003 CONTINUE
14 CONTINUE
WHITE (6,101)
WRITE (6,105)
DO 19 J=2,M
DO 19 K=2,N
J1=J-1
K1=K-1
WHITE (6,102) J1,K1,(COMG(J,K,I),I=1,3)
CONTINUE
RETURN.
END

```

•  
IWI M.F. FRSN

A SEG AFUEQ-\* (A,B,C,D)-E  
B SEG UNST1-UNST2-UNST3  
C SEG UNST4-UNST5-UNST6  
D SEG UNST7-UNST8  
E SEG UNST9-UNST10-UNST11  
F SEG NXPAF\$-NXPAX\$-EXP-ALOG-ATAN

• XGT PRSG

480.	180.	1.0	2.591E-4	1.0E7	.3	100.0
11 11	1.0E6	0.05	1.0	0.1	1.0	
480.	180.	1.0	2.591E-4	1.0E7	.333	100.0
11 11	1.0E6	0.05	1.0	0.1	1.0	
990.	126.	.3125	2.591E-4	1.0E7	.333	100.0
11 11	1.0E6	0.05	1.0	0.1	1.0	
2190.	198.	.5000	2.591E-4	1.0E7	.333	100.0
11 11	1.0E6	0.05	1.0	0.1	1.0	

• FIN

• FIN

```

101 NAF_PRSIV
    CHN      1
    SEG      NAFSEG=NAFREQ=0REIG=URT-HESSEN
    CHN      2
    SEG      DR1-UNST1-UNST2-UNST3
    CHN      3
    SEG      DR2-UNST4-UNST5-UNST6
    CHN      4
    SEG      DR3-UNST7-UNST8
    CHN      5
    SEG      DR4-UNST9-UNST10-UNST11
101 FOR      DR1
    COMMON L,S,U,V,W,PI,M,N,OMG(20,20,3),R,H,TO,CK,RI,GAM
    CALL UNST1 (PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL UNST2 (PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL UNST3 (PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL CHAIN(3)
    END
101 FOR      DR2
    COMMON L,S,U,V,W,PI,M,N,OMG(20,20,3),R,H,TO,CK,RI,GAM
    CALL UNST4 (PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL UNST5 (PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL UNST6 (PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL CHAIN(4)
    END
101 FOR      DR3
    COMMON L,S,U,V,W,PI,M,N,OMG(20,20,3),R,H,TO,CK,RI,GAM
    CALL UNST7 (PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL UNST8 (PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL CHAIN(5)
    END
101 FOR      DR4
    COMMON L,S,U,V,W,PI,M,N,OMG(20,20,3),R,H,TO,CK,RI,GAM
    CALL UNST9 (PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL UNST10(PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL UNST11(PI,R,H,TO,CK,RI,GAM,OMG,M,N)
    CALL CHAIN(1)
    END

```

#### 4.0 REFERENCES

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APPENDIX A  
GENERAL INFORMATION ON SOLUTION  
OF THE STABILITY EQUATIONS

A-I. The Constraints of the Computer Program

To determine the roots of the instability equations a Fortran IV program using an accelerated variation of The Method of Iteration was used. The iteration formula was programmed so that if the procedure does not iterate to a value that satisfies the instability equations to a specified degree of accuracy for a given case then an easily spotted nonsense answer will be printed out for this case.

- a. If after 10 initial guesses not one causes the argument of the arcsine, that appears as part of the function  $\beta$  in equation (7), to be less than one then

$$\text{COMG}(J,K,I) = .33333333$$

- b. If the initial guess of  $\Omega$  causes  $B(J,K,I) = \pi a^{\frac{1}{2}}/2$ , the argument of the trigonometric functions within  $\beta$  in equation (7), to be greater than  $2^{28}$  then

$$\text{COMG}(J,K,I) = .77777777$$

- c. If the iteration of  $\Omega$  causes  $B(J,K,I) = \pi a^{\frac{1}{2}}/2$  to be greater than  $2^{28}$  then

$$\text{COMG}(J,K,I) = .99999999$$

d. If after the specified number of iterations (usually either 100 or 1000) the iterates are not equal to within a preset value of each other and

- (1) The boundary condition of the Matheau [equation (1)],  
 $0 < a < 1$  is not being met then

$$\text{COMG}(J,K,I) = .66666666$$

- (2) The boundary condition is being met but  $a=1$  so that the iterate of  $\Omega$ ,  $X(3)$ , is approximately equal to  $C(J,K,I)$   
 $= [\Delta(0)]^{\frac{1}{2}}$  [equation (6)] to within .01 then

$$\text{COMG}(J,K,I) = .88888888$$

- (3) The boundary condition of  $0 < a < 1$  is met and  $X(3) \neq C(J,K,I)$   
then

$$\text{COMG}(J,K,I) = .11111111$$

- e. If iterates of  $\Omega$  are equal to within the preset value of each other but the Matheau boundary condition is not being met again

$$\text{COMG}(J,K,I) = .66666666$$

#### A-II. The Iteration Procedure

##### a. The Method of Iteration

The iteration procedure used was an accelerated version of The Method of Iteration. In order that one might understand

this variant a brief review of The Method of Iteration is given. (For a more complete development see ref. 3) Given a function

$$f(x) = 0$$

One can always add a function  $h(x)$

$$f(x) + h(x) = h(x)$$

to obtain

$$g(x) = h(x).$$

The simultaneous solutions of the resulting equations

$$y = g(x)$$

$$y = h(x)$$

are the real roots of

$$f(x) = 0 \quad (\text{ref. 1}).$$

To find the roots of

$$f(x) = 0$$

by The Method of Iteration,

$$y = h(x)$$

must be rewritten in the form

$$x = H(y)$$

and for convergence the equations must satisfy the condition

$$\left| \frac{dg(x)}{dx} \right|_{x=p} < \left| \frac{dh(x)}{d} \right|_{x=p}$$

where  $p$  is the desired root of

$$f(x) = 0.$$

The iterates are formed by substituting an approximate value,  $x_0$ , of the root  $p$  into the equation

$$y = g(x)$$

to get

$$y_0 = g(x_0).$$

A new approximate value of  $x$  is then derived from the equation

$$x = H(y),$$

$$x_1 = H(y_0).$$

This process is repeated until

$$|x_n - x_{n-1}| < C_1$$

and

$$|f(x_n)| < C_2$$

where  $C_1$  and  $C_2$  are a measure of the accuracy desired. If the slope of  $g(x)$  in the region of  $p$  is much smaller than  $h(x)$  then  $x_n$  will converge rapidly to the root.

Figure A-1 and Figure A-2 demonstrate the convergence of this iterative method graphically

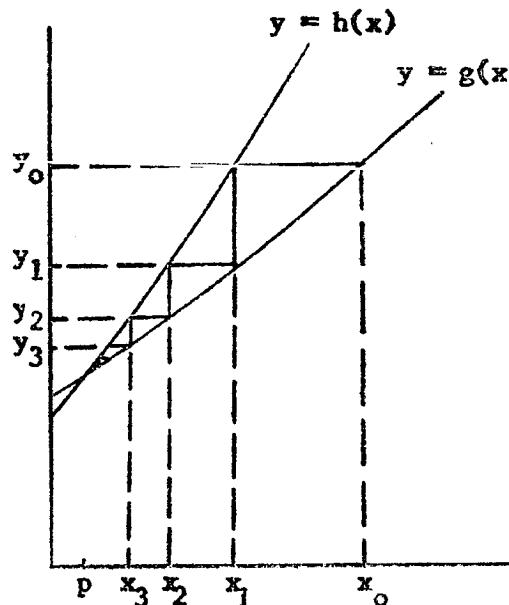


Figure A-1 - Slopes of  $g(x)$  and  $h(x)$  of Like Signs

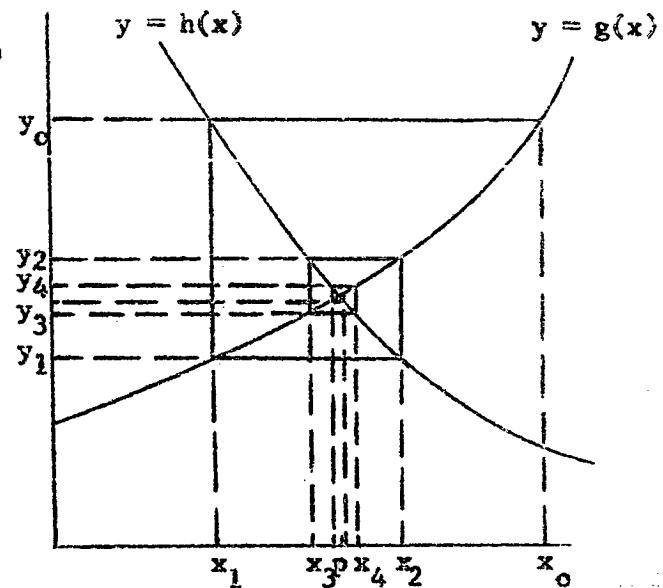


Figure A-2 - Slopes of  $g(x)$  and  $h(x)$  of Opposite Signs

In Figure A-1 the slopes of  $g(x)$  and  $h(x)$  are both of the same sign while in Figure A-2 they are of opposite sign. Points  $(x_0, y_0), (x_1, y_1), \dots, (x_i, y_i), \dots$  lie on the curve  $y = g(x)$  while points  $(x_0, y_0), (x_1, y_1), \dots, (x_i, y_{i-1}), \dots$  lie on the curve  $x = h(y)$  which is equivalent to the curve  $y = h(x)$ . When the slopes of the two functions have the same sign, the iteration follows a stepped path (Fig. A-1); when the slopes have opposite sign the iteration proceeds along a rectangular spiral (Fig. A-2).

Unfortunately, when one writes  $f(x) = 0$  in the form

$$y = g(x)$$

$$y = h(x),$$

one often has difficulty making sure that the slope of  $g(x)$  is much less than the slope of  $h(x)$  at the point of intersection and also that  $y = h(x)$  can be easily written in the form  $x = H(y)$ . However, if  $h(x) = x$ , then

$$f(x) = 0$$

becomes

$$f(x) + x = g(x) = x.$$

Now, using the equation  $y = x$  one gets the simultaneous relation

$$y = g(x)$$

$$y = x$$

If the slope of  $g(x)$  is small or zero, then these equations produce a rapidly converging iteration procedure. For a variant of this method involving derivatives see ref. 4.

#### b. An Accelerated Variation of the Method of Iteration

Another variant that will often accelerate the convergence of the iteration and does not use derivatives has an additional advantage of working even when

$$\left| \frac{dg(x)}{dx} \right|_{x=p} > \left| \frac{dh(x)}{dx} \right|_{x=p}$$

This method will be referred to as the Constructed Line Acceleration of the Method of Iteration. This variant also uses the two equations

$$y = g(x)$$

$$y = x$$

In this method, two points on

$$y = g(x)$$

are found by substituting the first approximate root,  $x_0$ , into

$$y = g(x)$$

yielding

$$y_0 = g(x_0).$$

Substitution of  $y_0$  into

$$y = x$$

yields

$$y_0 = x_1$$

The intersection of the line determined by the two points,  $(x_0, y_0)$  and  $(x_1, y_1)$  both on the curve  $y = g(x)$ , with the line

$$y = x$$

determines the abscissa of the third point. This process is repeated until the root is determined to within the desired degree of accuracy.

In Figure A-3 a graph of this method is presented. Notice that since

$$\left| \frac{d g(x)}{dx} \right|_{x=p} > \left| \frac{d h(x)}{dx} \right|_{x=p}$$

The standard form of The Method of Iteration would not work.

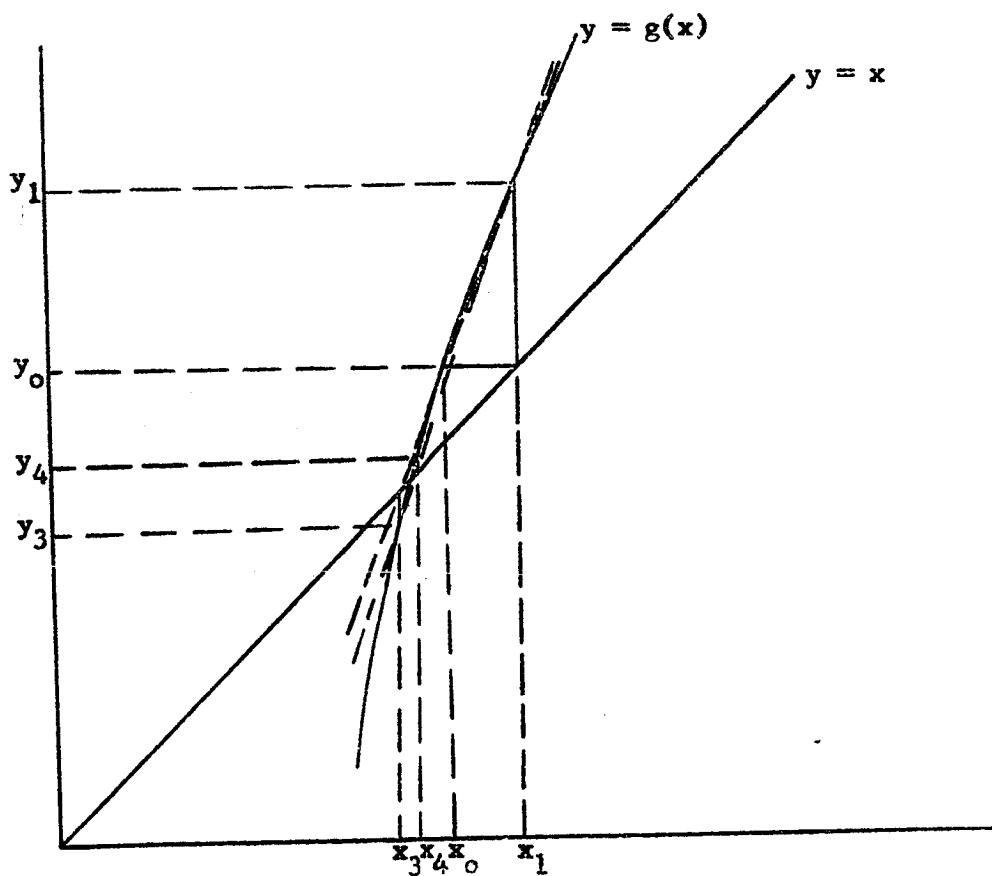


Figure A-3 - Constructed Line Acceleration of the Method of Iteration

The equation of the line through the two initial points on

$$y = g(x)$$

is

$$\frac{y - y_1}{x - x_1} = \frac{y_1 - y_0}{x_1 - x_0}$$

and at the intersection with the second of the two simultaneous equations from Figure A-3

$$y = x = x_2.$$

Combining

$$y = x_2$$

with the equation of the line through the two initial points one obtains an equation solvable for  $x_2$ , the abscissa of the point of intersection of these two lines. However, since

$$\frac{y - y_1}{x - x_1} = \frac{y_1 - y_0}{x_1 - x_0}$$

is an approximation of

$$y = g(x)$$

$x_2$  is an approximation of  $p$ , the root which is the abscissa of the point of intersection of

$$y = g(x)$$

and

$$y = x.$$

Thus substituting

$$y = x = x_2$$

in

$$\frac{y - y_1}{x - x_1} = \frac{y_1 - y_0}{x_1 - x_0}$$

one obtains

$$\frac{x_2 - y_1}{x_2 - x_1} = \frac{y_1 - y_0}{x_1 - x_0}$$

or

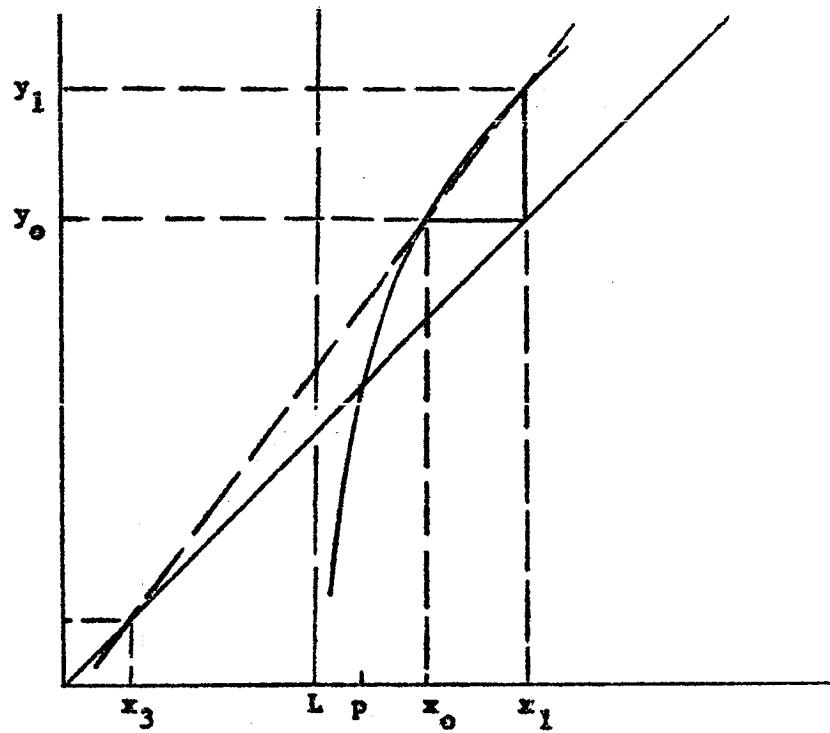
$$x_2 = \frac{x_1 y_0 - x_0 y_1}{x_1 - x_0 - y_1 + y_0}$$

or in general, the nth iterate is

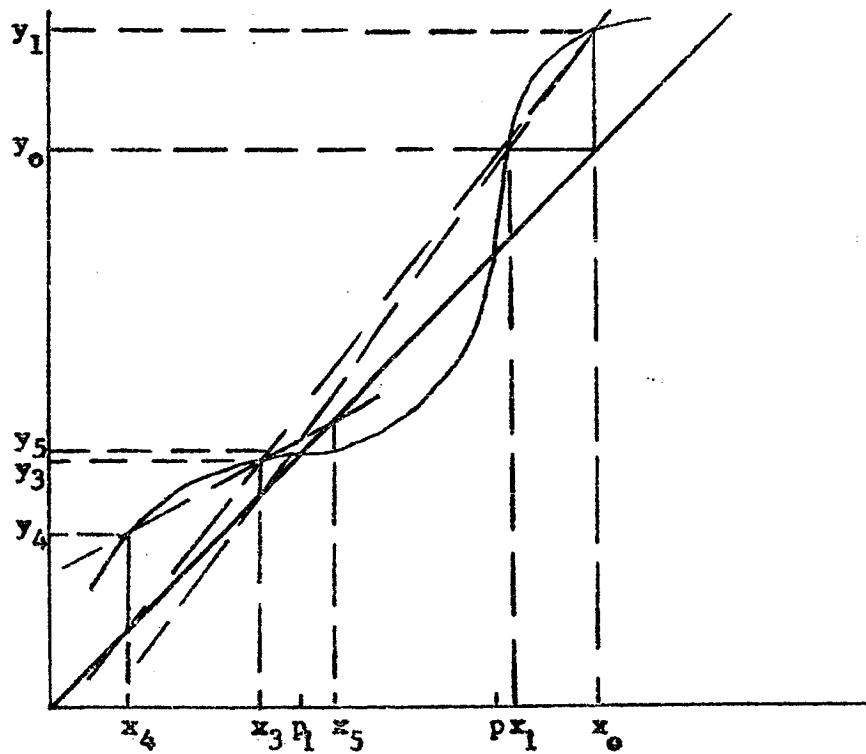
$$x_n = \frac{x_{n-1} g(x_{n-2}) - x_{n-2} g(x_{n-1})}{x_{n-1} - x_{n-2} - g(x_{n-1}) + g(x_{n-2})}$$

Restrictions

A case where this iteration formula will not iterate is diagrammed in Figure A-4.



**Figure A-4 - Example of Case Where The Constructed Line Acceleration Method Fails**



**Figure A-5 - Another Case Where The Constructed Line Acceleration Method Fails**

Since the function  $g(x)$  asymptotically approaches the line

$$x = L$$

there is no point of intersection between

$$y = g(x)$$

and

$$y = x_2.$$

But there is an intersection between

$$y = g(x)$$

and

$$x = y_2,$$

therefore, if the inverse of the function  $g(x)$  can be found,  
the iteration equation becomes

$$y_n = \frac{G(y_{n-1}) y_{n-2} - G(y_{n-2}) y_{n-1}}{G(y_{n-1}) - G(y_{n-2}) - y_{n-1} + y_{n-2}}$$

where

$$x_n = g(y_n).$$

Another function that the constructed line acceleration  
method will not iterate properly is illustrated in Figure A-5.

In this case the iteration is proceeding to a root  $p_1$  rather than the desired root  $p$ . However in the cases diagramed in Figures A-4 and A-5 and in the case where

$$\frac{y_1 - y_0}{x_1 - x_0} = 1$$

if  $x_0$ , the initial guess of  $p$ , the desired root, is near enough to  $p$  then the equation

$$x_n = \frac{x_{n-1} g(x_{n-2}) - x_{n-2} g(x_{n-1})}{x_{n-1} - x_{n-2} - g(x_{n-1}) + g(x_{n-2})}$$

will iterate  $x_n$  to  $p$  as long as  $g(x)$  is a single valued function and is defined on both sides of and at  $y = x$ .